

# **SITE-WIDE GROUNDWATER STUDY REPORT**

**TRADEPOINT ATLANTIC  
SPARROWS POINT, MARYLAND**

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## 1.0 INTRODUCTION

### 1.1. PURPOSE

The purpose of this document is to provide an evaluation of site-wide groundwater data that have been collected at the Tradepoint Atlantic property located in Baltimore County Maryland. The Tradepoint Atlantic property includes approximately 3100 acres comprising the Sparrows Point peninsula (Site). This evaluation of site-wide groundwater includes efforts to:

- Provide a summary of current groundwater conditions, including groundwater use and quality;
- Provide information to support the assessment of the United States Environmental Protection Agencies (USEPA) *Migration of Contaminated Groundwater Under Control Environmental Indicator (EI) RCRIS code (CA750)*).

### 1.2. PREVIOUS INVESTIGATIONS

There have been numerous extensive investigations to characterize groundwater at the Tradepoint Atlantic property at Sparrows Point.

An extensive Site-Wide Investigation (SWI) report was completed in 2001 (CH2M-Hill, 2001). The SWI provides hydrogeological and general water quality data across the entire Site and addresses the following objectives:

- To develop an improved understanding of the character and distribution of geologic materials from the ground surface to depths of 120 feet on a site-wide basis.
- To obtain information on the permeability of these geologic materials and on the distribution of hydraulic head within them.
- To obtain information on inputs and outputs of the groundwater flow systems in these geologic materials and on the interaction between groundwater and surface water within and adjacent to the Site.
- To integrate the geologic and groundwater information by developing a computer model of groundwater flow on a site-wide basis.
- To obtain preliminary information on the effects of historical groundwater conditions on vertical groundwater flow in the upper 120 feet at the Site.
- To develop an improved understanding of the current use of groundwater on-site and in adjacent communities.

A number of subsequent investigations have been completed to investigate specific areas of the Site to identify Constituents of Potential Concern (COPCs) in groundwater and to determine COPC concentrations. These investigations are summarized in the *Groundwater Conditions Executive Summary Report* (ARM, 2017). **Table 1** provides a summary of the previous

groundwater investigation reports and **Figure 1** shows the specific areas covered by individual groundwater investigation reports.

### **1.3. SITE HYDROGEOLOGY**

Three near-surface hydrogeologic, or groundwater, zones were identified from previous site investigations. According to the Site Wide Investigation Report of Nature & Extent of Releases to Groundwater from the Special Study Areas (SSAs) (URS 2005, revised 2007), these zones were designated shallow, intermediate, and lower. The hydrogeologic boundary elevations vary by several feet across the Sparrows Point facility.

The shallow water table below the Site occurs within recent sedimentary deposits or slag fill material, and includes the unconfined water table at the Site. Monitoring wells designated as shallow are screened within this shallow, unconfined unit. The “shallow” bottom-of-screen elevations generally range from +5 to -20 feet amsl. In some areas of the Site, the slag fill is directly underlain by and connected to the coarser grained beds or lenses within the Talbot Formation that comprise the Upper Talbot Channel Unit. In these areas, the slag fill and Upper Talbot Channel Units form a single groundwater flow system. In much of the investigation area, the slag fill material is underlain by finer-grained silts and clays that comprise the Talbot Clay Aquitard. In these areas, shallow groundwater flow may be separated from groundwater in any underlying coarse-grained beds or lenses.

The intermediate hydrogeologic zone includes the unconfined to partially confined groundwater in the Pleistocene Upper Talbot unit. The “intermediate” bottom-of-screen elevations generally range from -20 to -50 feet amsl. The presence of clay and silt layers within the intermediate hydrogeologic zone likely retard the vertical recharge of groundwater from the upper fill material.

The lower hydrogeologic zone includes the confined groundwater in the Lower Talbot or Upper Patapsco Sand unit. The “lower” bottom-of-screen elevations generally range from -50 to -141 feet amsl. The lower hydrogeologic zone was not a primary focus in this groundwater investigation. Hydrogeologic zones at greater depth are known to exist based on a review of the regional geology; however, these deeper units are isolated from the upper three units and impacts have not been identified from former iron and steel operations.

The shallow and intermediate hydrogeologic zones have been investigated thoroughly at the Site.

### **1.4. SUPPLEMENTAL INVESTIGATIONS**

Supplemental groundwater investigations were performed as described in the Site-Wide Groundwater Study Plan (dated May 5, 2017). These additional investigations included:

- a synoptic round of water level measurements to provide updated comprehensive groundwater elevation data for the shallow and intermediate groundwater zones, and
- sampling of selected wells that exhibited relative high total cyanide concentrations to determine the amount of available cyanide present.

## 2.0 GROUNDWATER USAGE

### 2.1. PREVIOUS GROUNDWATER USE SURVEY

Section 3.8 of the SWI describes the water supply and use study conducted in 2001. The objectives of this study were:

- 1) to document the construction of active on-site production wells, and
- 2) to document current off-site groundwater usage.

During the time of this investigation, six on-site production wells were present and either actively pumped or on stand-by for pumping activities. Blast Furnace No.3 and Town Well No.4 were continuously pumped at the time the study was conducted. Blast Furnace No.2 and Hot Strip Mill No. 10 wells were pumped on an as-needed basis (e.g. equipment failure in one of the continuous wells) at the time the study was conducted. The water pumped from these four wells was sent to the Pennwood Power Plant for use in steam generation for the Sparrows Point facility.

Construction logs were reviewed for four of the six production wells. The construction logs indicated that these wells were screened between 500 to 732 feet below ground surface (bgs). Well construction details for Caster Well No. 1 and Caster Well No.2 were not available for review. Caster No. 1 and Caster No. 2 wells were used on an as-needed pumping basis for the Continuous Caster Building. The water from these wells was used for cooling the slabs as they were produced. As a result, the wells were typically pumped during the summer months when the outside temperature was high enough to impede air cooling of the slabs.

As part of the SWI, a review of Baltimore County Department of Environmental Protection (BCDEP) potable water files was conducted which identified two potable water wells within a two mile radius of the Site. Further production well file research conducted at the Maryland Department of the Environment (MDE) identified eight (8) high-volume wells within a two-mile radius of the Site.

### 2.2. CURRENT USAGE

All pumping activities from the on-site production wells stopped operation with the closure of the steelmaking operations. Groundwater is not currently being extracted and used for any purpose at the Site, with the exception of groundwater monitoring procedures to characterize analytical properties and potentiometric surface investigations across the Site and groundwater extraction within the Coke Point Area in support of approved remedial measures.

Both the BCDEP and MDE were contacted to provide an updated list of wells within a one-mile radius of the Site. The BCDEP indicated that all data on wells would be available from the

MDE. MDE provided a report from the database of well drilling permits (**Appendix A**) which indicates the approximate location of the wells, the use of the wells, and well construction data. Most of the wells identified by the MDE are test wells on the Sparrows Point property. **Figure 2** shows the former on-site groundwater production well locations. **Figure 3** shows the locations of production wells identified in the MDE well database report within a 1 mile radius of the site. Test wells are not included on the figure since the purpose of these wells is not for potable groundwater use.

### **2.3. POTENTIAL FOR FUTURE USAGE**

The potential for future use from the potentially impacted groundwater hydrogeologic zones (to a depth of approximately 120 feet bgs) was assessed.

MDE categorizes aquifers on the following basis:

- Type I aquifer - has a transmissivity rate greater than 1,000 gallons/day/foot and a permeability rate greater than 100 gallons/day/square foot, and natural water with a total dissolved solids (TDS) concentration less than 500 milligrams/liter.
- Type II aquifer - has either
  - a transmissivity rate greater than 10,000 gallons/day/foot, a permeability rate greater than 100 gallons/day/square foot and natural water with a TDS concentration of between 500 and 6,000 milligrams/liter; or
  - a transmissivity rate between 1,000 and 10,000 gallons/day/foot, a permeability rate greater than 100 gallons/day/square foot and natural water with a TDS concentration of between 500 and 1,500 milligrams/liter.

Much of the groundwater investigated at the Site (particularly the shallow zone) flows through a slag fill unit that would not be representative of “natural water” in the aquifer unit. **Figure 4** shows the 1916 shoreline and the area of slag fill.

The boring logs and well construction logs were reviewed to identify which groundwater monitoring points are completed in slag fill. The top and bottom elevation of slag fill identified in each log was compared to the groundwater monitoring point screen interval and the measured groundwater elevation in each point. These elevations were used to determine and map the thickness of slag fill within the saturated zone. **Figure 5** shows the saturated thickness of slag fill in the screened interval of groundwater monitoring points as determined by the boring/well construction logs and measured groundwater elevations. As would be expected most of the locations where groundwater is present in slag fill are located beyond the historical 1916 shoreline.

Saltwater intrusion has been an issue at the Site due to past pumping for industrial water use. The SWI provides TDS and chloride concentrations for shallow and deep zone wells across the

Site. In addition, specific conductance (SC) data were collected during the sampling of each well across the Site as part of the Phase II investigations.

The SC data that was collected during the Phase II investigations was converted to equivalent TDS values ( $1000 \text{ } \mu\text{S}/\text{cm} = 534 \text{ mg/L TDS}$ ). These data points were used to develop TDS isoconcentration maps for each groundwater zone. **Figure 6** shows the TDS concentrations in the shallow zone and **Figure 7** shows the TDS concentrations in the intermediate zone.

**Figure 8** and **Figure 9** show the transmissivity of the shallow and intermediate aquifer based on the conductivity values in the SWI model and the aquifer thicknesses, respectively.

Groundwater associated with slag fill is known to exhibit basic pH concentrations rendering it unusable. pH values collected from the most recent sampling events from each well or piezometer were contoured to create maps (shallow and intermediate) showing pH contours and delineating areas of the site where the pH exceeds 10. These areas/zones are not to be considered usable aquifer, both due to the high pH and the likely occurrence of the groundwater in non-natural slag fill.

**Figure 10** shows the pH in the shallow zone. **Figure 11** shows the pH in the intermediate zone. As expected, the pH values in the shallow zone are indicative of the groundwater being present in slag fill within a large portion of the Site. The general pH concentration in the intermediate zone is within the acceptable range for groundwater use.

By overlaying the pH, TDS, and transmissivity data for the shallow zone, areas that exhibit no potential for future groundwater use have been delineated and are shown on **Figure 12**. These areas are considered to not contain usable groundwater.

### 3.0 GROUNDWATER DISCHARGE TO SURFACE WATER

Item 5 of the USEPA *Migration of Contaminated Groundwater Under Control Environmental Indicator (EI) RCRIS code (CA750)* requires an assessment of the degree to which contaminated groundwater is discharging to surface water. For the purposes of addressing Item 5, the data from the aforementioned groundwater investigations were screened to determine whether the discharge of “contaminated” groundwater into surface water is likely to be “insignificant” (i.e., the maximum concentration of each contaminant discharging into surface water is less than 10 times their appropriate groundwater “level”). COPCs for discharge to surface water were determined based on parameter concentrations in monitoring wells near the shoreline that exceed 10 times their applicable surface water quality criteria in perimeter wells.

#### 3.1. SUPPLEMENTAL CYANIDE INVESTIGATION

The analytical results for total cyanide in groundwater throughout the Site were screened to determine whether individual sample results exceeded the USEPA Vapor Intrusion Screening Levels (VISL) and the Numerical Criteria for Toxic Substances in Surface Waters (COMAR Section 26.08.02.03-2) for Aquatic Life Salt Water Chronic criteria and Human Health for Consumption of Organism Only criteria. Parameters and locations that may present a potential concern with respect to discharges of groundwater to surface water can be conservatively identified using the Numeric Criteria for Toxic Substances in Surface Waters. . One of the COPCs identified in groundwater at the Site with a potential to exceed the criteria was cyanide. The initial screening was based on total cyanide data for the wells, while the ambient water quality criteria are based on free or available cyanide. Therefore, the potential concern of groundwater discharges to surface water exceeding the Numeric Criteria for Toxic Substances in Surface Waters for cyanide in groundwater is likely overstated.

A focused supplemental investigation work plan was submitted to the Agencies to determine the form of cyanide present in the groundwater in select wells at the Site. The supplemental cyanide groundwater sampling event was conducted in accordance with the Proposed Available Cyanide Sampling (Revision 0) dated June 23, 2017, the QAPP Worksheet 21 – Field SOPs, SOP No. 006 – Groundwater Sampling, the MDE-Voluntary Cleanup Program, and the USEPA guidelines.

A total of 13 representative locations were selected for additional available cyanide sample collection. These locations were based on the highest results of total cyanide in groundwater. The locations of the wells sampled for available cyanide are shown in **Figure 13**. Permanent monitoring well SW-033-MWS was proposed for supplemental groundwater sampling due to a total cyanide detection of 81.1 ug/L; however SW-033-MWS was destroyed and could not be sampled. Permanent monitoring well SW-034-MWS was sampled in lieu of SW-033-MWS due to its proximity (approximately 670 feet east of SW-033-MWS) and total cyanide detection of 71.8 ug/L.

The results from the available cyanide groundwater sampling event are provided as **Table 2** and shown on **Figure 13**. The original total cyanide groundwater results are also provided for comparison. In addition to total and available cyanide groundwater results, **Table 2** compares the available cyanide results to the surface water discharge screening level of 10 times the Numeric Criteria for Toxic Substances in Surface Waters as well as the vapor intrusion screening level (VISL).

None of the available cyanide results exceeded 10 times the Numeric Criteria for Toxic Substances in Surface Water that would indicate cyanide to be a significant COPC for discharge to surface water. Only one supplemental sample location slightly exceeded the VISL of 3.5 ug/L with a detection of 5.3 ug/L at sample location LF-02. All other supplemental available cyanide sampling results were reported less than 3 ug/L.

Based on these results indicating that a very small fraction of the total cyanide in groundwater is present in the form of available cyanide, cyanide is no longer considered to be a significant COPC when addressing groundwater to surface water discharges or in evaluating indoor air vapor intrusion concerns.

### 3.2. GROUNDWATER POTENTIOMETRIC SURFACES

To improve the understanding of site-wide groundwater flow, a new synoptic round of groundwater level measurements was collected from wells across the Site. Water level measurements were collected from 127 groundwater monitoring points over a four day period from June 27 to 30, 2017. There were no precipitation events during this period. **Table 3** presents the groundwater elevation measurements collected during this event. These synoptic groundwater elevation measurements were used to generate groundwater contour maps for the shallow zone (**Figure 14**) and the intermediate zone (**Figure 15**). The resulting potentiometric surfaces have improved spatial resolution over the groundwater contour maps presented in the SWI because of the abundance of new wells that have been installed at the Site and were used to collect data for groundwater level measurements.

The refined site-wide groundwater contour map was used to divide the Site into localized discharge areas based on observed groundwater divides. **Figure 16** shows the Site divided into the following six (6) discharge areas (starting in the northwest and moving counterclockwise): the Parcel A9 discharge area, the Northwest discharge area, the Coke Oven discharge area, the Coke Point discharge area, the Turning Basin discharge area, and the Southeast discharge area. The Coke Point and Southeast discharge areas were further subdivided into the Coke Point sections 1 and 2 and the Southeast sections 1, 2, and 3.

### 3.3. GROUNDWATER DISCHARGE RATES

The groundwater discharge areas were broken into segments based on lithology, groundwater zone thickness and hydrologic properties.

The groundwater discharge rate along each discharge segment was calculated using Equation 1.

Equation 1:  $Q_{gw} = K_i A$

where:  $Q_{gw}$  = Discharge of groundwater

$K$  = hydraulic conductivity

$i$  = hydraulic gradient

$A$  = flow section flux plane cross-sectional area

The thickness of each groundwater zone was initially estimated from the SWI model, then adjusted based on the observed thicknesses in the boring logs and construction logs for the groundwater monitoring points installed during the Phase II investigations.

The potentiometric data collected during the synoptic water level measurements (**Table 3**) were used to determine hydraulic gradient calculations to estimate groundwater discharge rates representative of current conditions.

Hydraulic conductivity values of individual hydrogeologic units at the Site were sourced from the groundwater model developed in the SWI. The model in the SWI is particularly valuable because it was specifically calibrated for the Sparrows Point site based on the numerical findings of the hydrogeologic investigations. The computer modeling was performed using a modular, three-dimensional, finite difference code published by the United States Geological Survey (USGS) popularly known as MODFLOW.

The model was fully three-dimensional in function and discretized the Site into numerous hydrogeologic zones both laterally and vertically. The vertical zones were generally determined by lithology, which can be summarized as a surficial layer of slag fill underlain by alternating layers of clay and sand (enumerated Clay 1, Sand 1, Clay 2, etc.). The hydrogeologic model vertically extends to the top of the Sand 3 layer, at depths of 60 to 90 feet. Synoptic and continuous water-level data indicated that the effects of near-surface groundwater flow conditions (i.e., recharge from precipitation and discharge to surface water bodies) extend into the Sand 2 layer but not into the Sand 3 layer. Groundwater flow in the Sand 3 layer appears to be controlled by regional influences. This hydrogeologic separation of near-surface (i.e., local) vs. regional groundwater flow conditions makes Sand 3 a suitable bottom boundary for the model.

Previous groundwater investigations have typically separated hydrogeologic zones at the Site into the shallow, intermediate, and deep zones based on vertical soil unit observations. These zones generally correlate with the sand units described in the SWI. The shallow zone (bottom of screen elevations +5 to -20 feet above mean sea level (amsl)) essentially encompasses the Slag Layer and Sand 1, the intermediate zone (bottom of screen elevations -20 to -50 feet amsl) encompasses Sand 2, and the deep zone (bottom of screen elevations -50 to -141 feet amsl) encompasses Sand 3.

The following calibrated horizontal hydraulic conductivity values (in feet/day) were used in the SWI model:

Model Layer	Hydraulic Conductivity (feet/day)	
	Horizontal (Kh)	Vertical (Kv)
1 (slag unit)	0.045, 0.561, 20, 149, or 1,200 (See <b>Figure 4.1-4</b> )	Kh/10
2 (Clay 1)	0.825 or 0.561 (see <b>Figure 4.1-5</b> )	5.50E-03
3 (Sand 1)	47	Kh/10
4 (Clay 2)	1.00E-02	4.00E-04
5 (Sand 2)	47	Kh/10
6 (Clay 3)	1.00E-02	4.00E-04
7 (Sand 3)	47	Kh/10

Figures 4.1-4 and Figure 4.1-5 from the SWI are included in **Appendix B**.

These hydraulic conductivity values were used for the calculations of the rate of groundwater discharge to surface water.

**Table 4** presents a summary of the properties used and the groundwater discharge rates calculated for each segment of shoreline. The calculations are provided in **Appendix C**.

### 3.4. ESTIMATION OF CONTAMINANT DISCHARGE TO SURFACE WATER

The USEPA *Migration of Contaminated Groundwater Under Control Environmental Indicator (EI) RCRIS code (CA750)* item 6 poses the question “Can the discharge of “contaminated” groundwater into surface water be shown to be “currently acceptable” (i.e., not cause impacts to surface water, sediments or eco-systems that should not be allowed to continue until a final remedy decision can be made and implemented)? If it cannot be shown, (i.e., the discharge of “contaminated” groundwater into surface water is potentially significant), the EI requires documentation of the following:

- 1) The maximum known or reasonably suspected concentration of each contaminant discharged above its groundwater “level,” the value of the appropriate “level(s),” and if there is evidence that the concentrations are increasing; and
- 2) For any contaminants discharging into surface water in concentrations greater than 100 times their appropriate groundwater “levels,” the estimated total amount (mass in kg/yr) of each of these contaminants that are being discharged (loaded) into the surface water body (at the time of the determination), and identification of any potentially existing evidence that the amount of discharging contaminants is increasing.

To satisfy the requirements of the EI, the mass flux for contaminants present in groundwater discharging to surface water bodies surrounding the Sparrows Point peninsula was estimated for those principal COPCs that exceed surface water criteria by greater than a factor of 100 based on recent analytical data.

**Figure 17** shows all parameters across the Site that exceeded surface water criteria by a factor greater than 100 based on recent analytical data from the Phase II investigations. These parameters consisted of benzene, toluene, xylenes, and naphthalene in the Coke Oven/Coke Point discharge areas; iron, cobalt and zinc in the Northwest discharge area; and cobalt and manganese in the Southeast discharge area. Mass flux was calculated for these parameters, as well as any other constituent which had a concentration exceeding the screening level of 10x the ambient water quality criteria. These constituents are presented in **Table 5** for each of the discharge areas.

Upon calculation of the discharge ( $Q_{gw}$ ) across each flux plane, the contaminant mass flux was calculated using Equation 2.

Equation 2:  $F = CQ_{gw}$

where:  $F$  = Contaminant mass flux

$C$  = Average concentration of contaminant analytes using data from representative monitoring wells within the flow section and near the flux plane.

$Q_{gw}$  = groundwater discharge rate as determined using Equation 1

The contaminant mass flux for each COPC was calculated using the following input terms and equations:

- Concentration ( $C$ ) of each analyte identified above detection limits in monitoring wells near the flux plane.
- Flow rates of outfalls located near the terminal flux plane.

The concentrations of each of the surface water COPCs that exceeded the screening level of 10 times the surface water criteria in the perimeter wells/piezometers within each zone in the associated groundwater discharge area were averaged for the purposes of estimating the contaminant mass flux from the shallow groundwater zone to the surface water.

The mass flux of each COPC was evaluated on a separate basis for each of the discharge areas using the groundwater discharge rates calculated for each discharge segment. **Table 6** shows the average groundwater concentrations and the estimated mass flux for each COPC for each discharge segment.

## 4.0 SURFACE WATER IMPACT ASSESSMENT

Item 6 of the USEPA *Migration of Contaminated Groundwater Under Control Environmental Indicator (EI) RCRIS code (CA750)* addresses the issue of determining whether the discharge of ‘contaminated’ groundwater into surface water can be shown to be ‘currently acceptable’ (i.e., not cause impacts to surface water, sediments or eco-systems that should not be allowed to continue until a final remedy decision can be made and implemented).

### 4.1. PREVIOUS OFF-SHORE IMPACT ASSESSMENTS

Detailed off-shore impact assessments have been completed in previous investigations for two of the identified discharge areas at the Site.

#### 4.1.1. Northwest Discharge Area

The Phase I Offshore Investigation Report for the Sparrows Point Site (EA Engineering, Science and Technology, Inc., March 2016) details a recent investigation that was conducted in this discharge area (referred to as the Phase I area in this report). The Offshore Investigation for the Phase I area included collection of sediment, pore water, and stormwater samples to support evaluation of offshore impacts to Bear Creek from the Site. A primary objective of the investigation was to identify current Site-related impacts to the offshore environment. Accordingly, the pore water and stormwater data were used to model current Site-related impacts to surface water in the near-shore environment. In addition to current impacts along the shoreline in the northern portion of the Phase I area, the offshore investigation also sought to delineate historical impacts which appeared to be associated with the Tin Mill Canal. The objectives of the investigation also included conducting human health and ecological risk assessments, as well as providing information that will be considered in remedial decision making for the offshore area.

During the Phase I Offshore Investigation, the analytical suite for pore water was specifically selected from analytes that exceeded screening values in groundwater and stormwater, to allow a focus on how these onshore media affect the offshore area. In place of surface water sampling, a numerical model of constituent concentrations in surface water was designed to assess how current inputs via pore water and stormwater affect surface water quality. The concentrations of chemical constituents analyzed in sediment and modeled surface water formed the basis of the risk assessment. The human health and ecological risk assessments in this report evaluated the potential cumulative risks for human and ecological receptors from exposure to surface water, sediment, and fish and crab tissue within the Phase I area.

The off-shore report concluded that Site-related constituents in surface water only present a potential concern to aquatic life during stormwater events (i.e., unrelated to groundwater discharge). Modeling studies indicated that total cyanide could potentially exceed ambient

surface water quality criteria when stormwater discharges were added to the groundwater discharge.

The supplemental available cyanide investigation determined that the fraction of the total cyanide levels measured in the groundwater that is in the form of available cyanide is very small. None of the available cyanide levels exceeded the surface water impact screening level of 10 times the ambient water quality criterion. Therefore, based on the previous off-shore impact study and these supplemental available cyanide data, groundwater discharge to surface water is currently acceptable in the Northwest discharge area.

#### **4.1.2. Coke Oven & Coke Point Discharge Areas**

The Site Assessment for Proposed Coke Point Dredged Material Containment Facility at Sparrows Point (EA Engineering, Science and Technology, Inc., November 2009) details an investigation conducted on and surrounding the whole Coke Point peninsula. The field investigation included onshore and offshore components to characterize the nature and extent of impacts to fill material, surface water, surface sediment, and subsurface sediment. The offshore investigation was focused on surface water and sediment adjacent to the Coke Point Peninsula in the Patapsco River and the Turning Basin. The primary objective of the offshore investigation was to assess the effects of historical uses at the site, along with impacted groundwater fluxes, on the quality of the adjacent surface water and sediment. Factors that affect the mobility of the compounds of interest, and potential pathways for their transport to surface water and sediment were evaluated using groundwater mass flux calculations, models of surface water hydrodynamics, and sediment-water partitioning of groundwater-derived organics.

This investigation was followed by the Final Risk Assessment of Offshore Areas Adjacent to the Coke Point Dredged Material Containment Facility at Sparrows Point (EA Engineering, Science and Technology, Inc., November 2011). This human health risk assessment study found that the non-cancer hazard was in the acceptable range (less than or equal to 1 when rounded to one significant figure) but that the carcinogenic risk to a potentially exposed waterman could exceed the USEPA's acceptable risk range of 1E-6 to 1E-4. The carcinogenic risks in this area are primarily driven by total PCBs and the PAHs benzo[a]pyrene and dibenz[a,h]anthracene. The risk assessment indicated that the total risk to a potential exposed waterman across all media and exposure pathways could be as high as 2.2E-4.

Of that total cancer risk estimate, the risk associated with PAHs amounted to 1.4E-4 (63.5%). A revised carcinogenic potency factor for benzo[a]pyrene and the associated PAHs was published in the USEPA Integrated Risk Information System (IRIS) Recent Additions dated January 19, 2017. Using this updated potency factor, the cancer risk associated with the PAHs would decrease from 1.4E-4 to 1.9E-5. This change would decrease the total estimated cancer risk from 2.2E-4 to 1.0E-4, which is within the acceptable risk range.

Therefore, with this update, the existing risk assessment demonstrates that the impacts associated with discharges of groundwater from the Coke Oven and Coke Point Discharge Areas do not present an unacceptable risk to human health.

#### **4.2. PRELIMINARY IMPACT SCREENING ASSESSMENTS**

Screening assessments were completed to evaluate the potential impact of groundwater discharge to surrounding surface water within each of the discharge areas that had not been previously studied.

The screening assessment provides a preliminary analysis of mixing processes to assess the potential concentrations of COPCs in the surface water due to groundwater discharges. Estimated potential ambient surface water concentrations are then compared to the Numeric Criteria for Toxic Substances in Surface Water to evaluate the potential significance of the groundwater discharges.

For small tidal inlets or bays, such as Old Road Bay and the Turning Basin, tidal exchange with the larger Patapsco River is the most significant component of surface water mixing. In addition to the groundwater discharge, there also may be other freshwater inputs such as stream discharges or treated effluent discharges that should be accounted for in the surface water mixing analysis.

A tidal prism model was developed to simulate the surface water mixing in each of the tidal surface water bodies. The tidal prism is the volume of water that flows into and out of an inlet or bay with the flood and ebb of the tide. This tidal prism model is used to estimate the amount of clean water that is exchanged in a tidal cycle, the tidal exchange rate, between the inlet or bay and in this case the Patapsco River. The estimated groundwater discharge will be mixed with the tidal exchange as well as the freshwater flow inputs from streams and outfalls within the groundwater discharge area during the tidal cycle. For this simple model, the waters are assumed to be fully mixed. Therefore, the degree of mixing within the surface water body will be a function of the relative rate of groundwater discharge to the total exchange rate for the inlet or bay. The Tidal Prism Model calculations for each tidal bay area are described in detail in **Appendix D**.

The Tradepoint Atlantic property receives approximately 40 million gallons per day (MGD) of treated effluent from the Back River Wastewater Treatment Plant (BRWWTP). This effluent is passed through the Site and discharged through multiple outfalls as shown on **Figure 16**. The effluent flows to each outfall are provided in **Table 7**. The table provides the minimum daily, maximum daily, and average annual daily flow at each outfall. One of these outfalls discharges through the Pennwood Canal into Old Road Bay. Thus, the freshwater input to the tidal prism model for Old Road Bay includes the treated effluent discharge.

Two streams, Jones Creek or North Point Creek, discharge fresh water into Old Road Bay. There is no stream gauging station on either Jones Creek or North Point Creek to provide actual mean annual flow measurements and statistics related to the base flow of these watersheds. Therefore, mean annual flow data from nearby watersheds of similar size were utilized to develop an estimate of the base flow for Jones Creek and North Point Creek. **Figure 18** shows the approximate locations of the nearby stream gauging stations used in this analysis. **Table 8** shows the characteristics of the Jones Creek and North Point Creek watersheds as well as the characteristics of the watersheds for which gauging station data are available. In order to calculate an estimated base flow rate for the Jones Creek and North Point Creek watersheds, the standardized mean annual flow was calculated in gallons per day per square mile of watershed drainage area ( $\text{gpd}/\text{mi}^2$ ) for the six nearby gauging stations. The average standardized mean annual flow of the six gauging stations was calculated to be 927,445  $\text{gpd}/\text{mi}^2$ . The average standardized mean annual flow of the six gauging stations was multiplied by the Jones Creek watershed drainage area ( $1.44 \text{ mi}^2$ ). Using this method an estimated base flow of 1,337,405  $\text{gpd}$  was calculated for Jones Creek. The same average standardized mean annual flow of the six gauging stations was multiplied by the North Point Creek watershed drainage area ( $0.9 \text{ mi}^2$ ), and an estimated base flow of 834,701  $\text{gpd}$  was calculated for North Point Creek.

The groundwater contaminant mass flux for each COPC was mixed into the total daily surface water exchange rate, estimated as described above, to estimate the concentration of each COPC in the surface water. It was assumed that any concentration of COPCs in the freshwater base flow or the tidal exchange would be negligible. An estimate of resulting contaminant concentrations in the surface water body due to the contaminant mass flux associated with groundwater discharge was calculated using Equation 3:

Equation 3:  $C_{\text{sw}} = F/Q_{\text{sw}}$

where:  $C_{\text{sw}}$  = Estimated concentration in surface water body  
 $Q_{\text{sw}}$  = flow rate (total exchange rate) of surface water body

These estimated surface water concentrations were then compared to the surface water quality criteria for aquatic life and human consumption of organisms. This surface water mixing analysis is presented in **Table 9**.

#### 4.2.1. Parcel A9 Discharge Area

There has been no groundwater data collected from Parcel A9 to date. Therefore, groundwater flow and mass flux have not been evaluated for Parcel A9 drainage area. The Parcel A9 area is immediately upstream from the northwest discharge area studied in the off-shore investigation report as discussed in Section 4.1.1. This report did not identify any unacceptable impacts that may have been caused by discharges from the Parcel A9 area. A Phase II investigation is

planned for this parcel which will involve the characterization of groundwater. If groundwater is found to be contaminated significantly above (i.e., 100-times) surface water criteria, contaminant mass fluxes to surface water will be calculated.

#### **4.2.2. Turning Basin Discharge Area**

Groundwater discharge to the Turning Basin from the eastern shoreline of the Coke Point Peninsula was evaluated in the Coke Point Site Assessment report. However, wells installed more recently along the northern and eastern borders of the Turning Basin exhibited constituents (aluminum and thallium) at concentrations greater than 10-times applicable surface water quality criteria. Groundwater discharge, mass flux, and surface water mixing calculations were performed for these parameters. None of the resulting estimated surface water concentrations exceeded the applicable ambient surface water quality criteria. The estimated surface water concentrations are shown in **Table 9**.

#### **4.2.3. Southeast Discharge Area Segment 1 (Jones Creek)**

Concentrations of aluminum, cobalt, iron, manganese, and nickel exceeded 10-times the applicable surface water quality criteria in one or more wells in this discharge segment. Groundwater discharge, mass flux, and surface water mixing calculations were performed for these parameters.

Because there are no Back River effluent discharges into Jones Creek upstream of wells SW-047-MWS and SW-046-MWS, the surface water mixing that would occur would be with the base flow from Jones Creek and the tidal exchange flowing from Old Road Bay. The mixing analysis indicates that none of the resulting estimated surface water concentrations exceeded the applicable ambient surface water quality criteria. The estimated surface water concentrations are shown in **Table 9**.

#### **4.2.4. Southeast Discharge Area Segment 2 (Old Road Bay)**

Concentrations of aluminum, cobalt, iron, manganese, and nickel exceeded 10-times the applicable surface water quality criteria in one or more wells in this discharge segment. Groundwater discharge, mass flux, and surface water mixing calculations were performed for these parameters.

Old Road Bay receives freshwater base flow from Jones Creek and North Point Creek. In addition, Outfall 001 discharges treated Back River effluent to Old Road Bay through the Pennwood Canal. Therefore, the mixing that would occur would include the base flow from these freshwater sources and the tidal exchange flowing from the Patapsco River. The mixing analysis indicates that none of the estimated surface water concentrations exceed the ambient water quality criteria.

#### 4.2.5. Southeast Discharge Area Segment 3 (Patapsco River)

None of the perimeter wells along the section of the Southeast Discharge Area that fronts on the Patapsco River contained any constituents at levels greater than the surface water impact screening level of 10 times the surface water criteria. Therefore, no evaluation of surface water mixing was necessary for this segment.

## 5.0 PRELIMINARY AREAS OF POTENTIAL SIGNIFICANCE

The shallow groundwater zone over most of the Site is not a useable aquifer. Over much of the site the shallow groundwater is present in slag fill, and does not represent a natural aquifer. Much of the groundwater, generally corresponding to the areas of slag fill, has a pH above 10, making it generally unsuitable for use as a potable water supply.

Much of the intermediate groundwater zone has a high total dissolved solids level. This mostly corresponds to the area beyond the original 1916 shoreline, so most of the southern portion of the site is unsuitable for potable use.

The groundwater discharge from the Site has been shown to be currently acceptable except offshore of Parcel A9. Parcel A9 groundwater has not yet been characterized to determine if the discharge to surface water is currently acceptable. A work plan is being developed for investigation of this parcel. The Parcel A9 area is immediately upstream from the northwest discharge area studied in the off-shore investigation report as discussed in Section 4.1.1. This report did not identify any unacceptable impacts that may have been caused by discharges from the Parcel A9 area.

Further evaluation is needed to determine whether groundwater discharges in this specific area are currently acceptable.

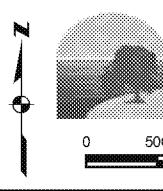
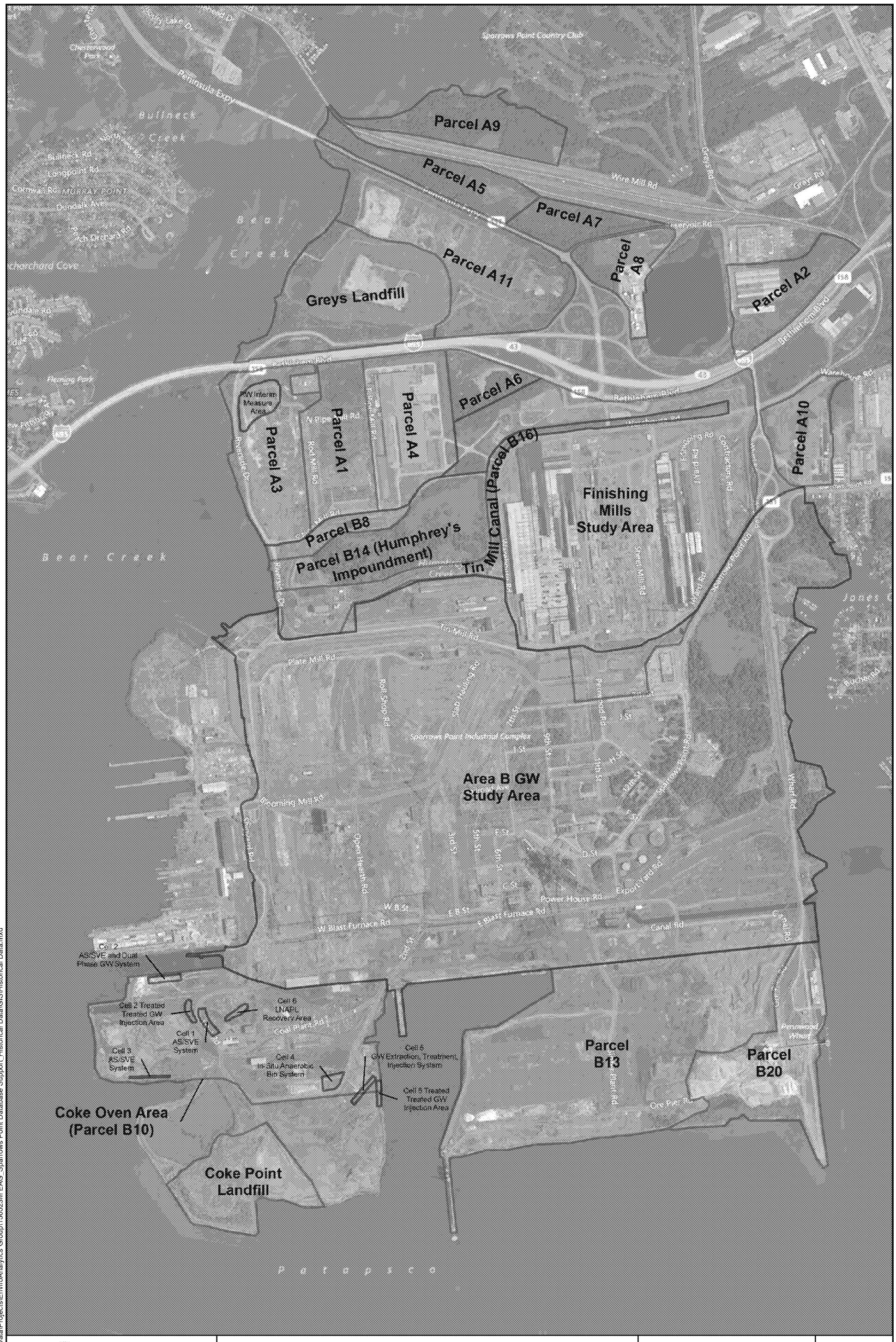
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## **FIGURES**

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**ARM Group Inc.**  
Earth Resource Engineers  
and Consultants

0 500 1,000 2,000  
Feet

## Site-Wide Groundwater Investigation Areas

February 10, 2017

EnviroAnalytics Group

Tradepoint Atlantic  
Baltimore County, MD

Figure  
**1**



 ARM Group Inc. Bath Resource Engineers and Consultants
Scale: 1" = 500'

## Groundwater Wells Within Project Area

Data Provided by Tradepoint Atlantic

EnviroAnalytics Group  
Tradepoint Atlantic  
Baltimore County, MD

Figure  
2

**Well Use**

-  Drinking Water
-  Fire Protection
-  Industrial
-  Site Boundary

BA735827

BA737085

BA736533

BA737332

BA730151

BA700348

BA811927

BA812741

BA812742

Permit Number	Well Use	Well Depth (ft)
BA700348	Drinking Water	70
BA730151	Fire Protection	80
BA735827	Drinking Water	50
BA736533	Fire Protection	100
BA737085	Drinking Water	70
BA737332	Fire Protection	100
BA811927	Fire Protection	70
BA812741	Industrial	650
BA812742	Industrial	650
BA920405	Drinking Water	100





**bing**

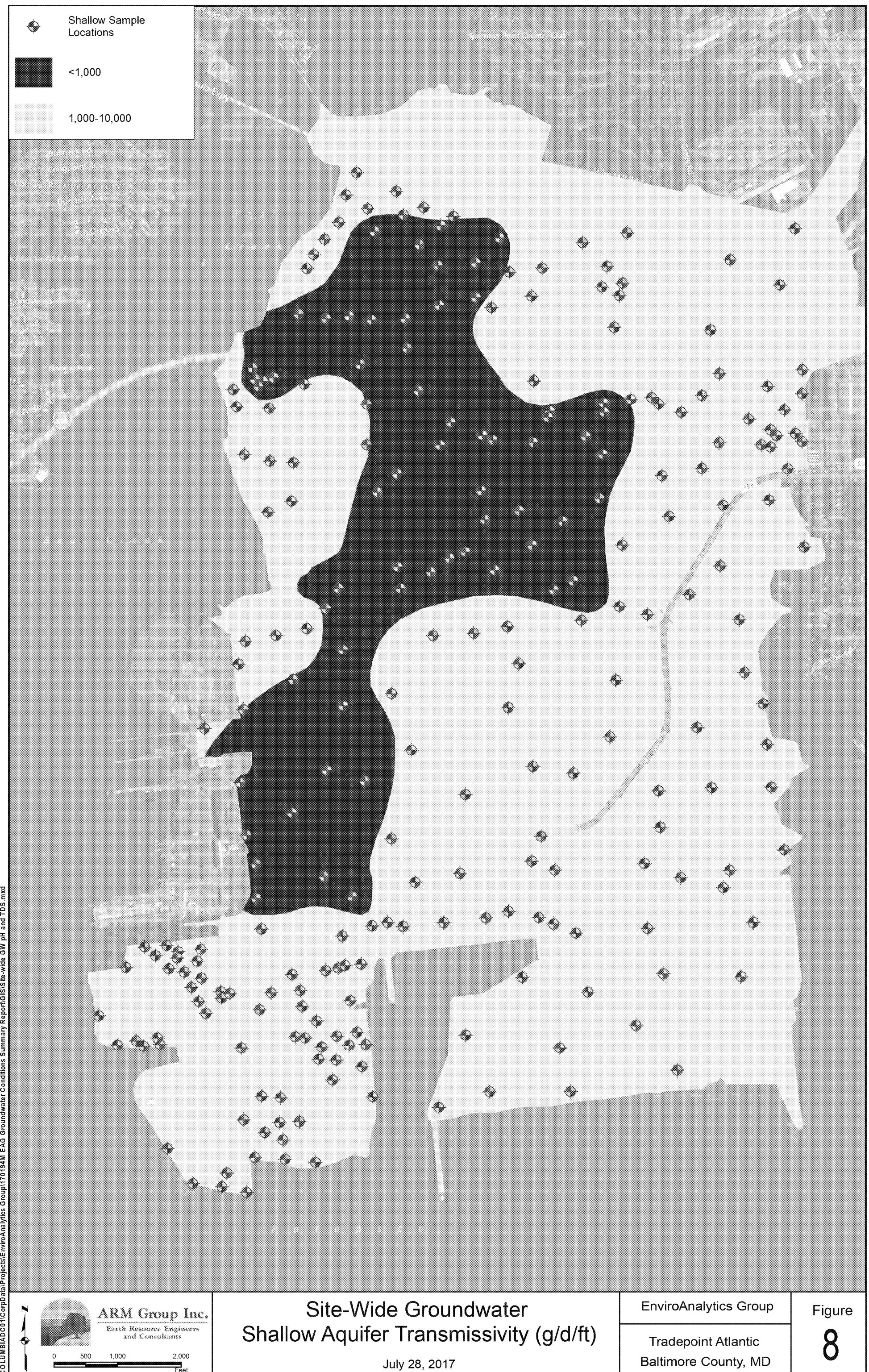
Image courtesy of USGS Earthstar Geographics, ©2014 Microsoft Corporation

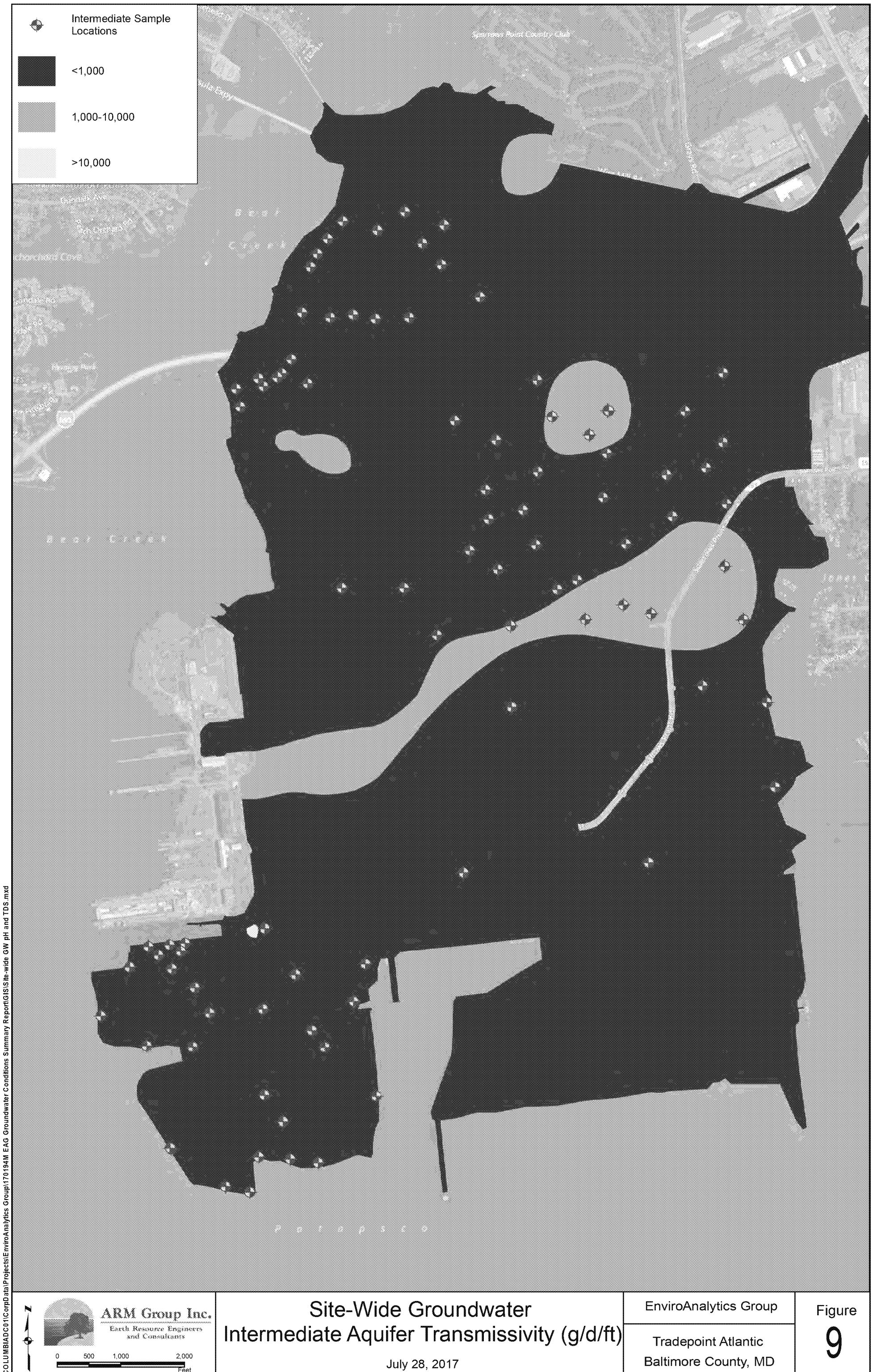
 <b>ARM Group Inc.</b> Environmental Engineering and Construction	<input type="checkbox"/> Site Boundary <input type="checkbox"/> Area A Boundaries <input type="checkbox"/> Area B Boundaries	<input type="checkbox"/> Land <input type="checkbox"/> Marsh <input checked="" type="checkbox"/> Water	<b>Approximate Shoreline 1916</b> <small>July 19, 2017</small>	EnviroAnalytics Group  Area A: Project 150298M Area B: Project 150300M	<b>Figure 4</b>
			<small>Adapted from Figure 2-5 of the Description of Current Conditions Report prepared by Rust Environmental and Infrastructure, dated January 1998</small>		





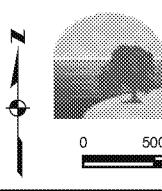








\COLUMBIAC01\EnviroAnalytics\Projects\EAG\Groundwater Conditions Summary Report\GIS\Site-wide GW pH and TDS.mxd



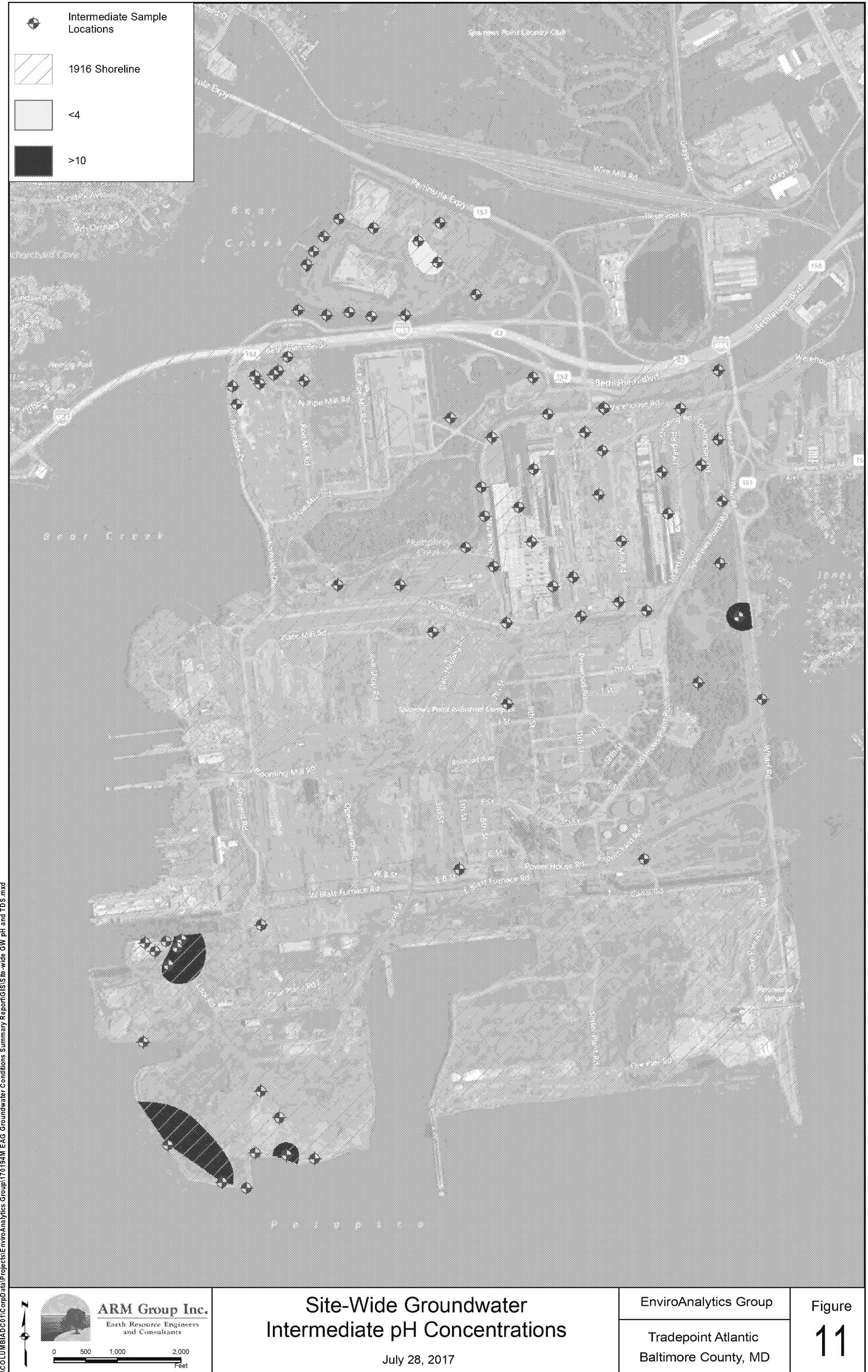
**ARM Group Inc.**  
Earth Resource Engineers  
and Consultants  
0 500 1,000 2,000  
Feet

## Site-Wide Groundwater Shallow pH Concentrations

July 28, 2017

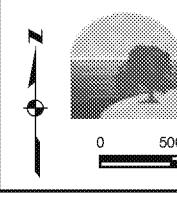
EnviroAnalytics Group  
Tradepoint Atlantic  
Baltimore County, MD

Figure  
**10**





C:\Users\skabis\Desktop\SP GIS temp\Site-wide GW pH and TDS -SK.mxd



**ARM Group Inc.**  
Earth Resource Engineers  
and Consultants

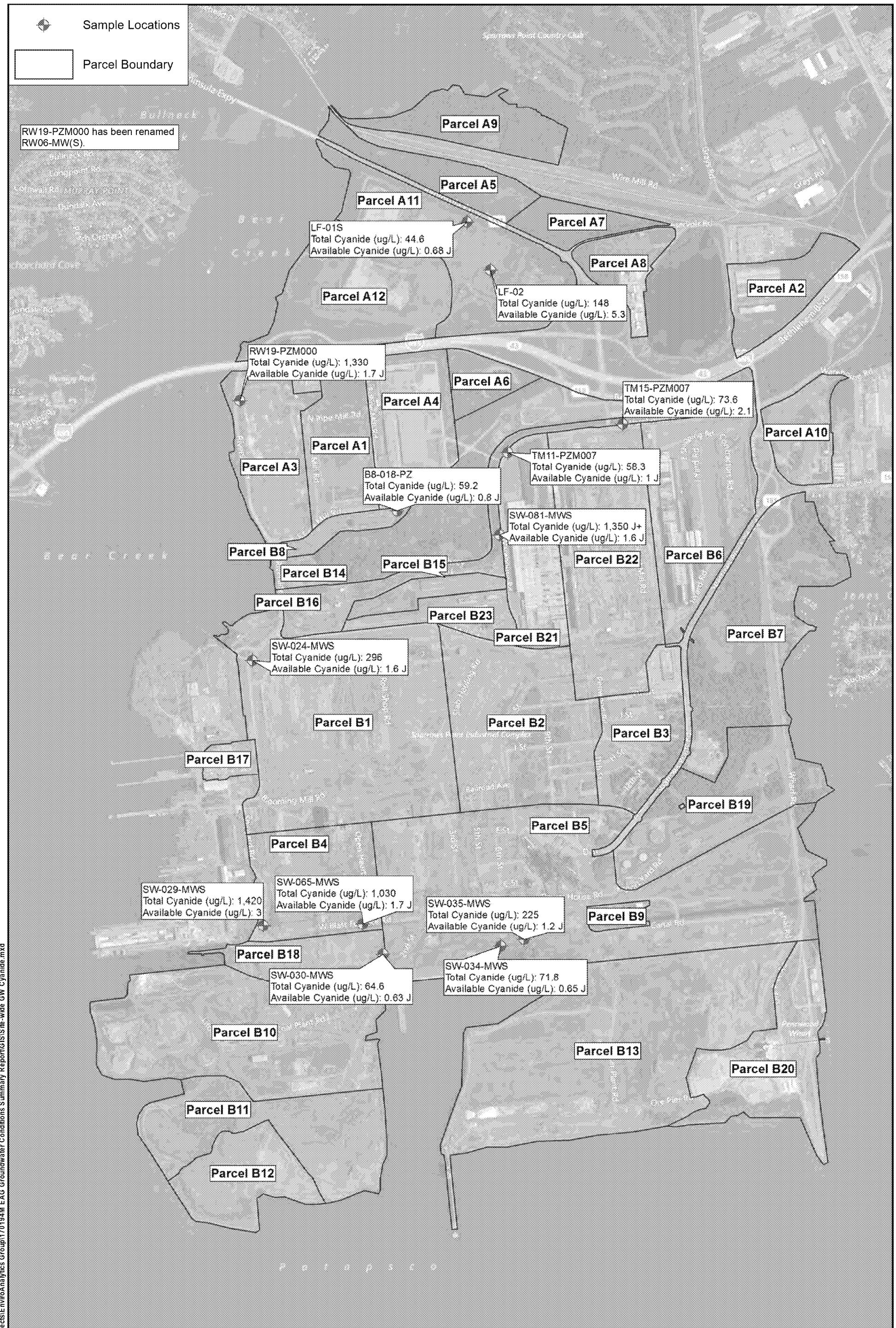
0 500 1,000 2,000  
Feet

## Site-Wide Shallow Groundwater Zone Unusable Groundwater Areas

August 8, 2017

EnviroAnalytics Group  
Tradepoint Atlantic  
Baltimore County, MD

Figure  
**12**



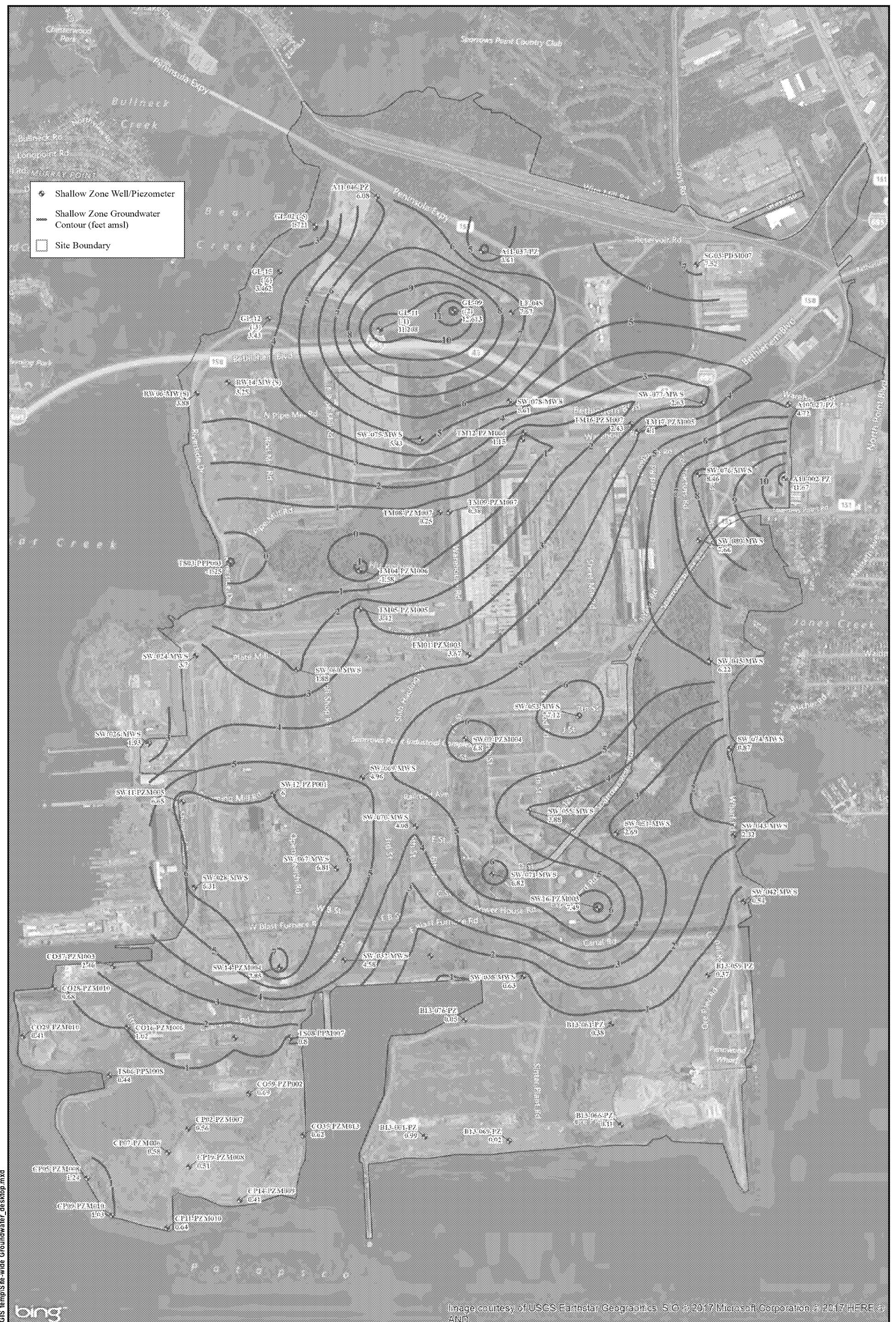
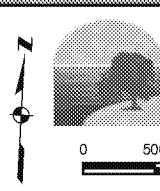


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and Consultants

A scale bar indicating distances from 0 to 2,000 feet. The bar is marked at 0, 500, 1,000, and 2,000. A horizontal line extends from the 2,000 mark to the right, labeled "Feet".

# Site-Wide Groundwater Shallow Zone Contours

July 29, 2017

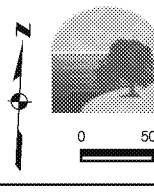
EnviroAnalytics Group

Tradepoint Atlantic  
Baltimore County, MD

# Figure 14

14

ED\_006416\_00000201-00038



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and Consultants

A horizontal scale bar representing distance in feet. The bar is divided into four segments by tick marks at 0, 500, 1,000, and 2,000 feet. The segment between 0 and 1,000 is shaded black, while the segments between 1,000 and 2,000, and beyond 2,000, are white. The word "Feet" is written below the scale bar.

# Site-Wide Groundwater Intermediate Zone Contours

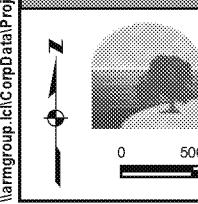
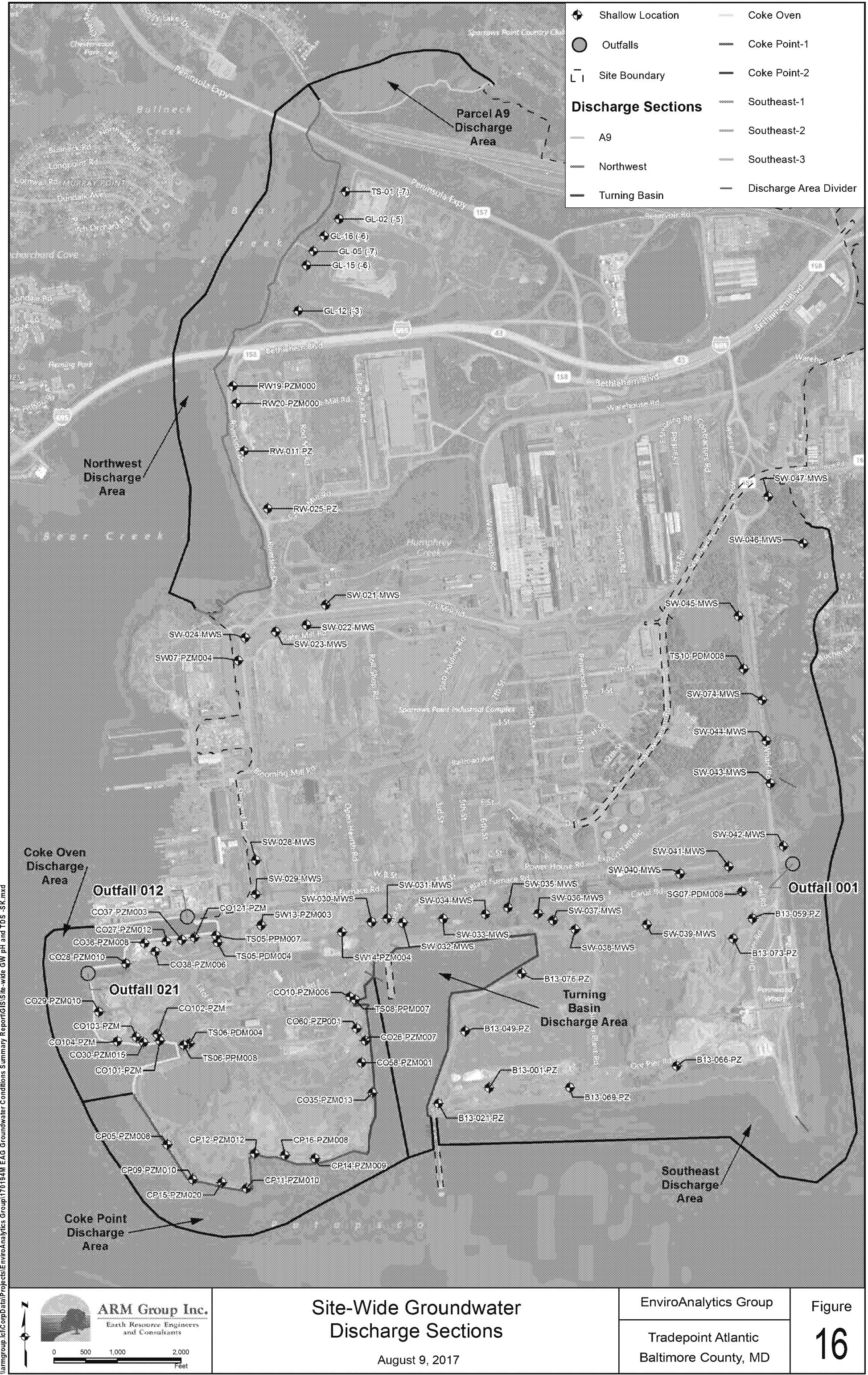
July 29, 2017

EnviroAnalytics Group

Tradepoint Atlantic  
Baltimore County, MD

# Figure 15

ED\_006416\_00000201-00039



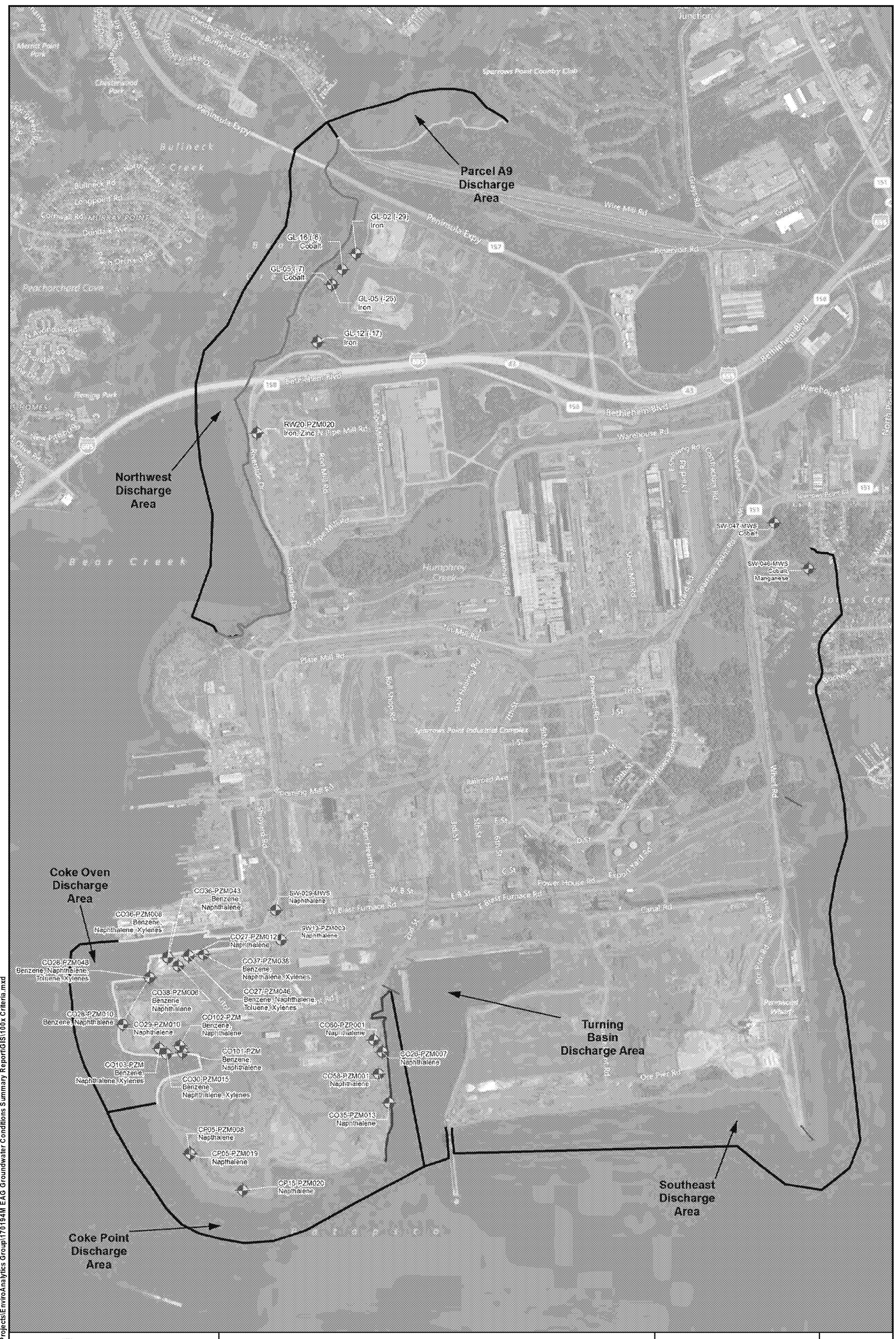
**ARM Group Inc.**  
Earth Resource Engineers  
and Consultants

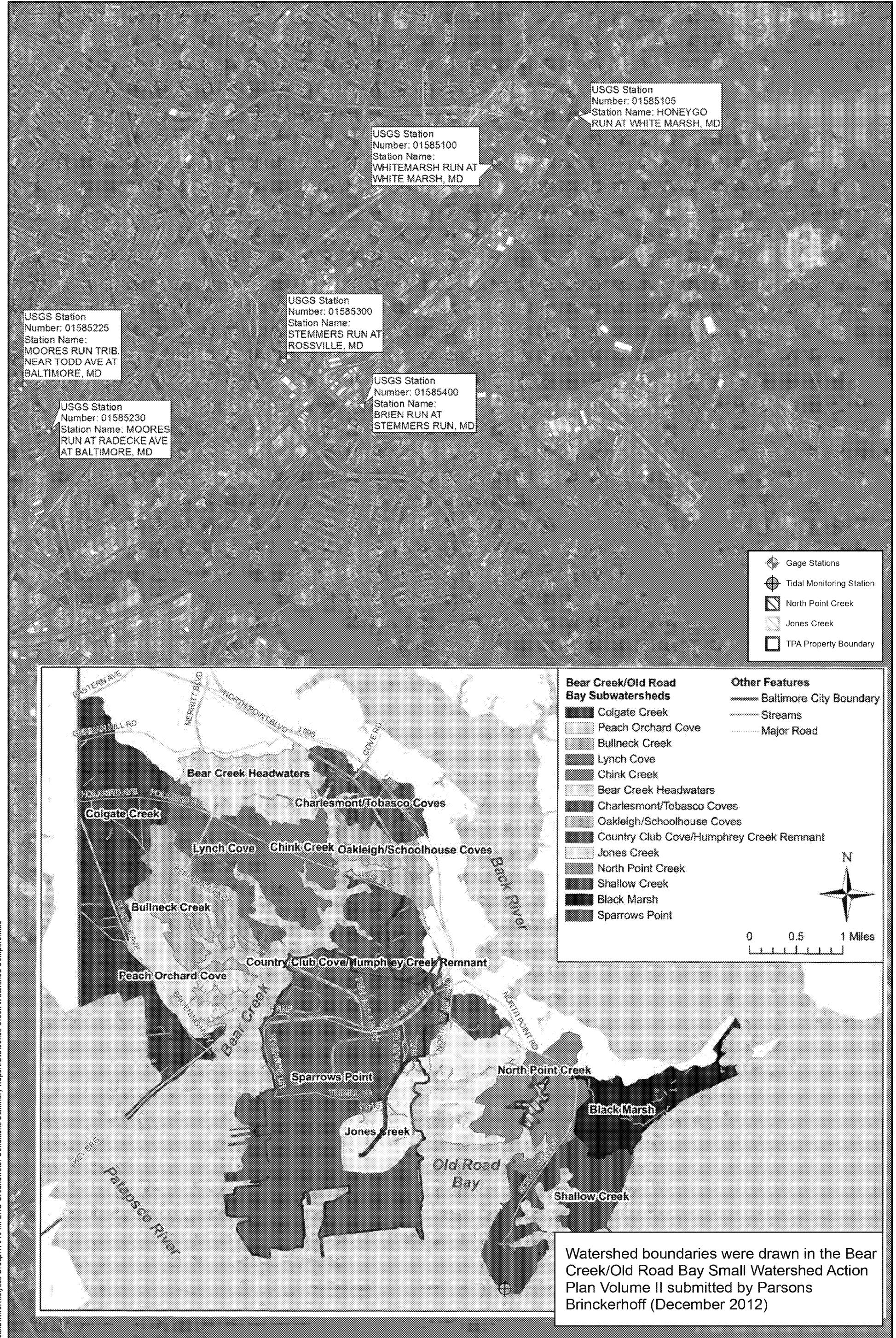
## Site-Wide Groundwater Discharge Sections

August 9, 2017

EnviroAnalytics Group  
Tradepoint Atlantic  
Baltimore County, MD

Figure  
**16**





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## **TABLES**

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**Table 1 - Historical Groundwater Reports**

Report	Author	Date of Report
Sparrows Point County Lands Summary Report	Rust Environment & Infrastructure	May 1, 1996
Description of Current Conditions (DCC) Report	Rust Environment & Infrastructure	January 1998
Site-Wide Investigation Work Plan - Groundwater Study	CH2M Hill	June 2000
Site-Wide Investigation Groundwater Study Report	CH2M Hill	July 2001
Site-Wide Investigation Release Site Characterization Study	CH2M Hill	June 2002
Site-Wide Investigation Report of Nature & Extent of Releases to Groundwater from the Special Study Areas	URS	January 2005
Site Assessment for Proposed Coke Point Dredged Material Containment Facility at Sparrows Point	EA Engineering, Science, and Technology, Inc.	Novemeber 2009
Parcel A1 (FedEx) Phase II ESA Report/RAP	Weaver Consultants Group	April 23, 2015
Pre-Design Investigation Summary Report - Former Coke Oven Area	Key Environmental, Inc	October 9, 2015 (Draft)
Phase I Offshore Investigation Report	EA Engineering, Science, and Technology, Inc.	March 2016
Parcel A3 Phase II Investigation Report	ARM Group, Inc.	June 10, 2016
Area B Groundwater Phase II Investigation Report	ARM Group, Inc.	September 30, 2016
Finishing Mills Groundwater Phase II Investigation Report	ARM Group, Inc.	November 30, 2016
Parcel B15 Phase II Investigation Report	ARM Group, Inc.	December 14, 2016
Parcel A2 Phase II Investigation Report	ARM Group, Inc.	December 19, 2016
Parcel A4 Phase II Investigation Report	ARM Group, Inc.	January 4, 2017
Parcel A8 Phase II Investigation Report	ARM Group, Inc.	January 11, 2017
Parcel A3 Phase II Investigation Report	ARM Group, Inc.	January 20, 2017
Parcel B8 Phase II Investigation Report	ARM Group, Inc.	February 7, 2017

**Table 2**  
**Total Cyanide and Available Cyanide Comparison**  
**Tradepoint Atlantic**  
**Sparrows Point, Maryland**

Sample ID	Unit	Vapor Intrusion Criteria	Ambient Water Quality Criteria				Total Cyanide Result	Available Cyanide Result
			Consumption of Organism Only Criteria	10x Consumption of Organism Only Criteria	Salt Water Chronic Criteria	10x Salt Water Chronic Criteria		
B8-018-PZ	ug/L	3.5	140	1,400	1	10	59.2	0.8 J
LF-01S	ug/L	3.5	140	1,400	1	10	44.6	0.68 J
LF-02	ug/L	3.5	140	1,400	1	10	148	5.3
RW19-PZM000	ug/L	3.5	140	1,400	1	10	1,330	1.7 J
SW-024-MWS	ug/L	3.5	140	1,400	1	10	296	1.6 J
SW-029-MWS	ug/L	3.5	140	1,400	1	10	1,420	3
SW-030-MWS	ug/L	3.5	140	1,400	1	10	64.6	0.63 J
SW-034-MWS	ug/L	3.5	140	1,400	1	10	71.8	0.65 J
SW-035-MWS	ug/L	3.5	140	1,400	1	10	225	1.2 J
SW-065-MWS	ug/L	3.5	140	1,400	1	10	1,030	1.7 J
SW-081-MWS	ug/L	3.5	140	1,400	1	10	1,350 J+	1.6 J
TM11-PZM007	ug/L	3.5	140	1,400	1	10	58.3	1 J
TM15-PZM007	ug/L	3.5	140	1,400	1	10	73.6	2.1

**Table 3**  
**Groundwater Elevation Measurements**

Well	Area/Parcel	Zone	Date	Time	DTW	TOC Elev.	GW Elev.
A10-002-PZ	A10	Shallow	6/29/2017	1139	10.46	22.13	11.67
A10-027-PZ	A10	Shallow	6/29/2017	1130	11.66	16.38	4.72
A11-037-PZ	A11	Shallow	6/29/2017	812	12.89	16.5	3.61
A11-046-PZ	A11	Shallow	6/30/2017	1030	14.66	20.74	6.08
B13-001-PZ	B13	Shallow	6/30/2017	1000	18.76	19.75	0.99
B13-021-PZ	B13	Shallow	4/4/2017	---	13.2	13.89	0.69
B13-049-PZ	B13	No TOC (Shallow)	6/28/2017	847	20.01	No TOC	N/A
B13-059-PZ	B13	Shallow	6/28/2017	946	28.55	28.92	0.37
B13-061-PZ	B13	Shallow	6/28/2017	936	31.23	31.61	0.38
B13-066-PZ	B13	Shallow	6/28/2017	916	6.49	6.6	0.11
B13-069-PZ	B13	Shallow	6/28/2017	902	23.31	23.33	0.02
B13-076-PZ	B13	Shallow	6/28/2017	841	17.04	17.09	0.05
CO02-PZM041	Coke Oven	Intermediate	6/27/2017	1057	15.52	13.88	-1.64
CO04-PZM048	Coke Oven	Intermediate	6/27/2017	1350	12.42	12.27	-0.15
CO09-PZM007	Coke Oven	Shallow	6/27/2017	1327	10.12	11.15	1.03
CO13-PZM030	Coke Oven	Intermediate	6/27/2017	901	13.96	12.15	-1.81
CO16-PZM006	Coke Oven	Shallow	6/27/2017	1053	11.86	12.88	1.02
CO28-PZM010	Coke Oven	Shallow	6/27/2017	1105	11.66	12.34	0.68
CO28-PZM048	Coke Oven	Intermediate	6/27/2017	1101	12.12	12.69	0.57
CO29-PZM010	Coke Oven	Shallow	6/27/2017	1043	14.45	14.86	0.41
CO29-PZM051	Coke Oven	Intermediate	6/27/2017	1047	12.98	13.48	0.50
CO32-PZM041	Coke Oven	Intermediate	6/27/2017	1032	13.2	13.15	-0.05
CO35-PZM013	Coke Oven	Shallow	6/27/2017	840	10.44	11.06	0.62
CO35-PZM056	Coke Oven	Intermediate	6/27/2017	837	10.59	11.26	0.67
CO37-PZM003	Coke Oven	Shallow	6/27/2017	1113	9.88	12.34	2.46
CO37-PZM038	Coke Oven	Intermediate	6/27/2017	1109	12.13	12.12	-0.01
CO59-PZP002	Coke Oven	Shallow	6/27/2017	903	16.06	16.75	0.69
CP02-PZM007	CPLF	Shallow	6/30/2017	916	21.86	22.42	0.56
CP05-PZM008	CPLF	Shallow	6/30/2017	935	9.09	10.33	1.24
CP05-PZM028	CPLF	Intermediate	6/27/2017	1016	10.02	7.07	-2.95
CP07-PZM006	CPLF	Shallow	6/30/2017	943	13.42	14.00	0.58
CP08-PZM034	CPLF	Intermediate	6/27/2017	933	25.56	25.47	-0.09

**Table 3**  
**Groundwater Elevation Measurements**

Well	Area/Parcel	Zone	Date	Time	DTW	TOC Elev.	GW Elev.
CP09-PZM010	CPLF	Shallow	6/30/2017	930	6.6	7.63	1.03
CP11-PZM010	CPLF	Shallow	6/27/2017	1008	7.79	8.43	0.64
CP11-PZM040	CPLF	Intermediate	6/27/2017	1010	10.02	7.64	-2.38
CP14-PZM009	CPLF	Shallow	6/27/2017	957	12.65	13.06	0.41
CP14-PZM062	CPLF	Intermediate	6/27/2017	958	12.97	13.67	0.70
CP19-PZM008	CPLF	Shallow	6/30/2017	924	22.04	22.55	0.51
FM01-PZM003	Area B	Shallow	6/28/2017	1027	6.41	10.08	3.67
FM05-PZM024	FM	Intermediate	6/28/2017	1001	9.7	14.47	4.77
GL-02 (-5)	GLF	Shallow	6/29/2017	827	21.45	23.171	1.72
GL-03 (-16)	GLF	Intermediate	6/29/2017	807	13.05	17.298	4.25
GL-05 (-25)	GLF	Intermediate	6/29/2017	841	24.51	25.189	0.68
GL-08 (-36)	GLF	Intermediate	6/29/2017	802	15.92	16.648	0.73
GL-09 (-2)	GLF	Shallow	6/29/2017	746	3.75	16.363	12.61
GL-09 (-20)	GLF	Intermediate	6/29/2017	744	10.32	16.14	5.82
GL-11 (-1)	GLF	Shallow	6/29/2017	738	10.14	21.348	11.21
GL-11 (-33)	GLF	Intermediate	6/29/2017	739	11.82	21.982	10.16
GL-12 (-17)	GLF	Intermediate	6/29/2017	728	12.2	12.809	0.61
GL-12 (-3)	GLF	Shallow	6/29/2017	726	9.89	13.32	3.43
GL-15 (-6)	GLF	Shallow	6/29/2017	837	12.33	15.792	3.46
GL-17 (-31)	GLF	Intermediate	6/29/2017	823	20.7	21.175	0.48
HI07-PZM032	B8/HI	Intermediate	6/28/2017	1253	8.74	11.58	2.84
LF-04S	A11	Shallow	6/29/2017	755	11.84	19.51	7.67
MW93-001	A7	No TOC (Shallow)	6/29/2017	1029	5.95	No TOC	N/A
MW93-003	A7	No TOC (Shallow)	6/29/2017	1111	13.6	No TOC	N/A
RW01-MW(I)	RWM	No TOC (Intermediate)	6/28/2017	1308	10.59	No TOC	N/A
RW01-MW(S)	RWM	No TOC (Shallow)	6/28/2017	1309	10.26	No TOC	N/A
RW06-MW(I)	RWM	Intermediate	6/28/2017	1312	12.15	13.53	1.38
RW06-MW(S)	RWM	Shallow	6/28/2017	1317	9.07	12.95	3.88
RW09-MW(I)	RWM	No TOC (Intermediate)	6/28/2017	1319	10.69	No TOC	N/A
RW09-MW(S)	RWM	No TOC (Shallow)	6/28/2017	1321	7.83	No TOC	N/A
RW12-MW(I)	RWM	Intermediate	6/30/2017	1005	11.2	12.94	1.74
RW14-MW(S)	RWM	Shallow	6/28/2017	1333	8.92	12.17	3.25

**Table 3**  
**Groundwater Elevation Measurements**

Well	Area/Parcel	Zone	Date	Time	DTW	TOC Elev.	GW Elev.
RW19-MW(I)	RWM	No TOC (Intermediate)	6/28/2017	1337	10.81	No TOC	N/A
RW19-MW(S)	RWM	No TOC (Shallow)	6/28/2017	1339	7.01	No TOC	N/A
SG03-PDM007	High Head Reservoir	Shallow	6/29/2017	929	5.96	13.48	7.52
SW01-PZM030	A7	Intermediate	6/29/2017	1320	23.31	24.20	0.89
SW-024-MWS	Area B	Shallow	6/27/2017	1425	10.33	14.03	3.70
SW-026-MWS	Area B	Shallow	6/27/2017	1420	9.58	11.51	1.93
SW-028-MWS	Area B	Shallow	6/27/2017	1130	9.28	15.59	6.31
SW-032-MWS	Area B	Shallow	6/27/2017	1230	8.06	12.64	4.58
SW-034-MWS	Area B	Shallow	6/27/2017	1548	11.37	12.62	1.25
SW-038-MWS	Area B	Shallow	6/27/2017	1553	15.65	16.28	0.63
SW-042-MWS	Area B	Shallow	6/28/2017	703	6.86	7.4	0.54
SW-043-MWI	Area B	Intermediate	6/28/2017	710	8.31	10.43	2.12
SW-043-MWS	Area B	Shallow	6/28/2017	716	7.94	10.26	2.32
SW-045-MWI	Area B	Intermediate	6/28/2017	820	12.79	12.86	0.07
SW-045-MWS	Area B	Shallow	6/28/2017	822	6.88	13.1	6.22
SW-051-MWS	Area B	Shallow	6/27/2017	1653	10.71	13.4	2.69
SW-053-MWS	Area B	Shallow	6/28/2017	831	6.72	13.84	7.12
SW-055-MWS	Area B	Shallow	6/27/2017	1615	7.99	11.87	3.88
SW05-PZM039	A10	Intermediate	6/29/2017	1125	11.59	18.14	6.55
SW-060-MWS	Area B	Shallow	6/27/2017	1432	12.24	14.12	1.88
SW-067-MWS	Area B	Shallow	6/27/2017	1533	8.04	14.85	6.81
SW-069-MWS	Area B	Shallow	6/27/2017	1529	11.6	16.56	4.96
SW06-PZM053	FM	Intermediate	6/28/2017	739	16.55	16.75	0.20
SW-070-MWS	Area B	Shallow	6/27/2017	1539	7.09	11.17	4.08
SW-071-MWS	Area B	Shallow	6/27/2017	1602	9.81	16.63	6.82
SW-074-MWI	Area B	Intermediate	6/28/2017	720	9.09	10.2	1.11
SW-074-MWS	Area B	Shallow	6/28/2017	821	10.45	11.32	0.87
SW-075-MWI	FM	Intermediate	6/28/2017	1424	12.81	13.09	0.28
SW-075-MWS	FM	Shallow	6/28/2017	1426	7.1	12.53	5.43
SW-076-MWI	FM	Intermediate	6/28/2017	1530	11.46	16.45	4.99
SW-076-MWS	FM	Shallow	6/28/2017	1534	7.9	16.36	8.46
SW-077-MWI	FM	Intermediate	6/28/2017	1502	10.72	12.34	1.62

**Table 3**  
**Groundwater Elevation Measurements**

Well	Area/Parcel	Zone	Date	Time	DTW	TOC Elev.	GW Elev.
SW-077-MWS	FM	Shallow	6/28/2017	1503	9.51	12.14	2.63
SW-078-MWI	FM	Intermediate	6/28/2017	1430	15.07	13.47	-1.60
SW-078-MWS	FM	Shallow	6/28/2017	1432	7.83	13.44	5.61
SW-079-MWI	FM	Intermediate	6/28/2017	1039	11.7	14.19	2.49
SW-080-MWI	FM	Intermediate	6/28/2017	1542	9.1	13.85	4.75
SW-080-MWS	FM	Shallow	6/28/2017	1545	6.41	14.07	7.66
SW09-PZM004	Area B	Shallow	6/27/2017	1640	6.36	13.16	6.8
SW09-PZM028	Area B	Intermediate	6/27/2017	1637	7.82	12.7	4.88
SW11-PZM005	Area B	Shallow	6/27/2017	1411	6.89	13.54	6.65
SW12-PZP001	Area B	Shallow	6/27/2017	1506	11.66	17.66	6.0
SW13-PZM025	Area B	Intermediate	6/27/2017	1240	16.61	15.59	-1.02
SW14-PZM004	Area B	Shallow	6/27/2017	1237	8	15.85	7.85
SW15-PZM031	Area B	Intermediate	6/27/2017	1524	13.24	14.9	1.66
SW16-PZM003	Area B	Shallow	6/27/2017	1609	7.45	14.94	7.49
TM02-PZM028	TMC/Humphreys Impoundment	Intermediate	6/28/2017	1109	10.78	10.43	-0.35
TM03-PZM037	Area B	Intermediate	6/28/2017	1140	10.63	12.08	1.45
TM04-PZM006	TMC/Humphreys Impoundment	Shallow	6/28/2017	1134	13.64	12.06	-1.58
TM04-PZM028	TMC/Humphreys Impoundment	Intermediate	6/28/2017	1132	12	11.91	-0.09
TM05-PZM005	Area B	Shallow	6/28/2017	1202	9.34	12.76	3.42
TM05-PZM040	Area B	Intermediate	6/28/2017	1158	10.46	12.83	2.37
TM08-PZM007	TMC/Humphreys Impoundment	Shallow	6/28/2017	1235	9.5	9.75	0.25
TM08-PZM038	TMC/Humphreys Impoundment	Intermediate	6/28/2017	1237	9.65	9.76	0.11
TM09-PZM007	FM	Shallow	6/28/2017	1218	10.9	11.28	0.38
TM09-PZM047	FM	Intermediate	6/28/2017	1216	11.41	11.19	-0.22
TM12-PZM006	FM	Shallow	6/28/2017	1436	11.11	12.26	1.15
TM13-PZM007	FM	Shallow	6/28/2017	1448	11.66	12.24	0.58
TM15-PZM031	FM	Intermediate	6/28/2017	1453	10.85	11.04	0.19
TM16-PZM007	FM	Shallow	6/28/2017	1507	9.86	12.29	2.43
TM17-PZM005	FM	Shallow	6/28/2017	1458	7.09	11.19	4.10
TS03-PPP003	TMC/Humphreys Impoundment	Shallow	6/28/2017	1101	15.86	14.61	-1.25
TS06-PPM008	Coke Oven	Shallow	6/27/2017	1030	12.77	13.21	0.44
TS08-PPM007	Coke Oven	Shallow	6/27/2017	1315	11.79	12.59	0.80

**Table 4 - Groundwater Discharge Rates**

Discharge Segment	Length (Feet)	Hydraulic Gradient	Hydraulic Conductivity (ft/day)	Average Saturated Thickness (feet)	Q (ft^3/day)	Q (gal/day)	Total Discharge (gal/day)
<b>Southeast Discharge Area</b>							
Segment SE-1	Slag Layer (Model Layer 1)	6011	0.009666	195.38	2.62	29,728	222,381
	Clay 1 (Model Layer 2)	6011	0.009666	0.54	2.22	69.6	521
	Sand 1 (Model Layer 3)	6011	0.009666	47	3.16	8,634	64,584
<b>Segment SE-2</b>							
	Slag Layer (Model Layer 1)	6345	0.0181	124.46	7.60	108,543	811,960
	Clay 1 (Model Layer 2)	6345	0.0181	0.18	2.17	45.7	342
	Sand 1 (Model Layer 3)	6345	0.0181	47	2.59	13,990	104,652
<b>Segment SE-3</b>							
	Slag Layer (Model Layer 1)	6351	0.0017	149	4.94	8,007	59,897
	Clay 1 (Model Layer 2)	6351	0.0017	0.56	0.63	3.82	28.5
	Sand 1 (Model Layer 3)	6351	0.0017	47	1.25	639	4,783
<b>Turning Basin</b>							
	Slag Layer (Model Layer 1)	6769	0.0044	97.77	2.87	8,290	62,011
	Clay 1 (Model Layer 2)	6769	0.0044	0.025	1.28	0.95	7.10
	Sand 1 (Model Layer 3)	6769	0.0044	47	1.45	2,015	15,073
<b>Coke Point</b>							
Segment CP-1	Slag Layer (Model Layer 1)	5083	0.0177	149	5.04	67,535	505,199
	Clay 1 (Model Layer 2)	5083	0.0177	0.025	0.50	1.13	8.42
	Sand 1 (Model Layer 3)	5083	0.0177	47	1.00	4,231	31,650
<b>Segment CP-2</b>							
	Slag Layer (Model Layer 1)	3256	0.0105	149	7.36	37,652	281,659
	Clay 1 (Model Layer 2)	3256	0.0105	0.025	3.50	3.01	22.5
	Sand 1 (Model Layer 3)	3256	0.0105	47	1.75	2,825	21,132
<b>Coke Oven</b>							
	Slag Layer (Model Layer 1)	8349	0.0011	149	9.21	12,953	96,892
	Clay 1 (Model Layer 2)	8349	0.0011	0.025	1.50	0.35	2.65
	Sand 1 (Model Layer 3)	8349	0.0011	47	2.81	1,247	9,329
<b>North west</b>							
	Slag Layer (Model Layer 1)	10701	0.0144	60.08	2.98	27,621	206,620
	Clay 1 (Model Layer 2)	10701	0.0144	0.27	0.61	25.2	189
	Sand 1 (Model Layer 3)	10701	0.0144	47	2.06	14,885	111,346

**Table 5**  
**10x Surface Water Criteria Exceedances**  
**Site-Wide Groundwater Study**

Discharge Area	Sample Location	Parameter	Unit	PAL Aqueous	Result	Flag	10x Organism Only (µg/L)	Factor of Exceedance	Exceeds 10x Organism Only	10x Salt Water Chronic	Factor of Exceedance	Exceeds 10x Salt Water Chronic
Coke Oven	CO101-PZM	Benzene	µg/L	5	17,400		5,100	3.41	YES	1,100	15.8	YES
Coke Oven	CO101-PZM	Naphthalene	µg/L	0.17	2,150		N/A	N/A	no	14	154	YES
Coke Oven	CO101-PZM	Xylenes	µg/L	10,000	249		N/A	N/A	no	130	1.92	YES
Coke Oven	CO102-PZM	Benzene	µg/L	5	15,700		5,100	3.08	YES	1,100	14.3	YES
Coke Oven	CO102-PZM	Naphthalene	µg/L	0.17	875		N/A	N/A	no	14	62.5	YES
Coke Oven	CO102-PZM	Xylenes	µg/L	10,000	238		N/A	N/A	no	130	1.83	YES
Coke Oven	CO103-PZM	Benzene	µg/L	5	27,700		5,100	5.43	YES	1,100	25.2	YES
Coke Oven	CO103-PZM	Naphthalene	µg/L	0.17	12,300		N/A	N/A	no	14	879	YES
Coke Oven	CO103-PZM	Xylenes	µg/L	10,000	960		N/A	N/A	no	130	7.38	YES
Coke Oven	CO27-PZM012	Benzene	µg/L	5	16,100		5,100	3.16	YES	1,100	14.6	YES
Coke Oven	CO27-PZM012	Naphthalene	µg/L	0.17	5,670		N/A	N/A	no	14	405	YES
Coke Oven	CO27-PZM012	Toluene	µg/L	1,000	5,390		150,000	0.04	no	2,150	2.51	YES
Coke Oven	CO27-PZM012	Xylenes	µg/L	10,000	1,500		N/A	N/A	no	130	11.5	YES
Coke Oven	CO30-PZM015	Benzene	µg/L	5	52,800		5,100	10.4	YES	1,100	48.0	YES
Coke Oven	CO30-PZM015	Naphthalene	µg/L	0.17	1,830		N/A	N/A	no	14	131	YES
Coke Oven	CO30-PZM015	Toluene	µg/L	1,000	3,620		150,000	0.02	no	2,150	1.68	YES
Coke Oven	CO30-PZM015	Xylenes	µg/L	10,000	1,060		N/A	N/A	no	130	8.15	YES
Coke Oven	CO36-PZM008	Benzene	µg/L	5	21,300		5,100	4.18	YES	1,100	19.4	YES
Coke Oven	CO36-PZM008	Naphthalene	µg/L	0.17	723		N/A	N/A	no	14	51.6	YES
Coke Oven	CO36-PZM008	Toluene	µg/L	1,000	4,610		150,000	0.03	no	2,150	2.14	YES
Coke Oven	CO36-PZM008	Xylenes	µg/L	10,000	1,370		N/A	N/A	no	130	10.5	YES
Coke Oven	CO38-PZM006	Benzene	µg/L	5	10,700		5,100	2.10	YES	1,100	9.73	YES
Coke Oven	CO38-PZM006	Ethylbenzene	µg/L	700	269		21,000	0.01	no	250	1.08	YES
Coke Oven	CO38-PZM006	Naphthalene	µg/L	0.17	6,620		N/A	N/A	no	14	473	YES
Coke Oven	CO38-PZM006	Toluene	µg/L	1,000	7,210		150,000	0.05	no	2,150	3.35	YES
Coke Oven	CO38-PZM006	Xylenes	µg/L	10,000	2,120		N/A	N/A	no	130	16.3	YES
Coke Oven	SW-028-MWS	Thallium, Dissolved	µg/L	2	4.8	J	4.7	1.02	YES	170	0.03	no
Coke Oven	SW-029-MWS	Benzo[a]pyrene	µg/L	0.2	1.2	J	1.8	0.67	no	0.14	8.57	YES
Coke Oven	SW-029-MWS	Naphthalene	µg/L	0.17	162		N/A	N/A	no	14	11.6	YES
Coke Oven	SW13-PZM003	Benz[a]anthracene	µg/L	0.0298	0.33		1.8	0.18	no	0.27	1.22	YES
Coke Oven	SW13-PZM003	Naphthalene	µg/L	0.17	169		N/A	N/A	no	14	12.1	YES
Coke Point-1	CP05-PZM008	Naphthalene	µg/L	0.17	142		N/A	N/A	no	14	10.1	YES
Coke Point-1	CP05-PZM019	Naphthalene	µg/L	0.17	180		N/A	N/A	no	14	12.9	YES
Coke Point-1	CP09-PZM010	Naphthalene	µg/L	0.17	61.5		N/A	N/A	no	14	4.39	YES
Coke Point-1	CP11-PZM010	Naphthalene	µg/L	0.17	92.8		N/A	N/A	no	14	6.63	YES
Coke Point-1	CP12-PZM012	Naphthalene	µg/L	0.17	80.5		N/A	N/A	no	14	5.75	YES
Coke Point-1	CP14-PZM009	Naphthalene	µg/L	0.17	42.9		N/A	N/A	no	14	3.06	YES
Coke Point-1	CP15-PZM020	Naphthalene	µg/L	0.17	319		N/A	N/A	no	14	22.8	YES

**Table 5**  
**10x Surface Water Criteria Exceedances**  
**Site-Wide Groundwater Study**

Discharge Area	Sample Location	Parameter	Unit	PAL Aqueous	Result	Flag	10x Organism Only (µg/L)	Factor of Exceedance	Exceeds 10x Organism Only	10x Salt Water Chronic	Factor of Exceedance	Exceeds 10x Salt Water Chronic
Coke Point-1	CP16-PZM008	Naphthalene	µg/L	0.17	19		N/A	N/A	no	14	1.36	YES
Coke Point-2	CO26-PZM007	Naphthalene	µg/L	0.17	6,130	L1	N/A	N/A	no	14	438	YES
Coke Point-2	CO26-PZM007	Xylenes	µg/L	10,000	337		N/A	N/A	no	130	2.59	YES
Coke Point-2	CO58-PZM001	Naphthalene	µg/L	0.17	3,040	L1	N/A	N/A	no	14	217	YES
Coke Point-2	CO58-PZM001	Xylenes	µg/L	10,000	249		N/A	N/A	no	130	1.92	YES
Coke Point-2	CO60-PZP001	Naphthalene	µg/L	0.17	676		N/A	N/A	no	14	48.3	YES
Coke Point-2	SW14-PZM004	Aluminum	µg/L	20,000	1,740		N/A	N/A	no	870	2.00	YES
Coke Point-2	SW14-PZM004	Aluminum, Dissolved	µg/L	20,000	1,850		N/A	N/A	no	870	2.13	YES
Coke Point-2	SW14-PZM004	Benz[a]anthracene	µg/L	0.0298	0.33		1.8	0.18	no	0.27	1.22	YES
Coke Point-2	SW14-PZM004	Naphthalene	µg/L	0.17	49.5		N/A	N/A	no	14	3.54	YES
Coke Point-2	SW14-PZM004	Thallium	µg/L	2	5.9	J	4.7	1.26	YES	170	0.03	no
Northeast	GL-05 (-7)	Total Cobalt	µg/L	6	170		N/A	N/A	no	10	17.0	YES
Northeast	GL-05 (-7)	Total Iron	µg/L	14,000	37,200		N/A	N/A	no	10,000	3.72	YES
Northeast	GL-05 (-7)	Total Nickel	µg/L	390	245		46,000	0.01	no	82	2.99	YES
Northeast	GL-12 (-3)	Total Cobalt	µg/L	6	74.9		N/A	N/A	no	10	7.49	YES
Northeast	GL-12 (-3)	Total Iron	µg/L	14,000	11,100		N/A	N/A	no	10,000	1.11	YES
Northeast	GL-12 (-3)	Total Nickel	µg/L	390	108		46,000	0.002	no	82	1.32	YES
Northeast	GL-16 (-6)	Total Cobalt	µg/L	6	262		N/A	N/A	no	10	26.2	YES
Northeast	GL-16 (-6)	Total Iron	µg/L	14,000	15,700		N/A	N/A	no	10,000	1.57	YES
Northeast	GL-16 (-6)	Total Nickel	µg/L	390	382		46,000	0.01	no	82	4.66	YES
Northeast	RW-025-PZ	Aluminum, Dissolved	µg/L	20,000	1,540		N/A	N/A	no	870	1.77	YES
Northeast	RW19-PZM000	Arsenic	µg/L	10	14.6	J	14	1.04	YES	360	0.04	no
Northeast	RW20-PZM000	Arsenic	µg/L	10	118		14	8.43	YES	360	0.33	no
Southeast-1	SW-044-MWS	Iron	µg/L	14,000	63,400		N/A	N/A	no	10,000	6.34	YES
Southeast-1	SW-044-MWS	Iron, Dissolved	µg/L	14,000	53,700		N/A	N/A	no	10,000	5.37	YES
Southeast-1	SW-044-MWS	Manganese	µg/L	430	3,060		N/A	N/A	no	1,000	3.06	YES
Southeast-1	SW-044-MWS	Manganese, Dissolved	µg/L	430	3,430		N/A	N/A	no	1,000	3.43	YES
Southeast-1	SW-045-MWS	Cobalt	µg/L	6	64.7		N/A	N/A	no	10	6.47	YES
Southeast-1	SW-045-MWS	Cobalt, Dissolved	µg/L	6	65.1		N/A	N/A	no	10	6.51	YES
Southeast-1	SW-045-MWS	Manganese	µg/L	430	1,140		N/A	N/A	no	1,000	1.14	YES
Southeast-1	SW-045-MWS	Manganese, Dissolved	µg/L	430	1,100		N/A	N/A	no	1,000	1.10	YES
Southeast-1	SW-045-MWS	Nickel	µg/L	390	103		46,000	0.002	no	82	1.26	YES
Southeast-1	SW-045-MWS	Nickel, Dissolved	µg/L	390	105		46,000	0.002	no	82	1.28	YES
Southeast-1	SW-046-MWS	Cobalt	µg/L	6	214		N/A	N/A	no	10	21.4	YES
Southeast-1	SW-046-MWS	Cobalt, Dissolved	µg/L	6	216		N/A	N/A	no	10	21.6	YES
Southeast-1	SW-046-MWS	Iron	µg/L	14,000	12,600		N/A	N/A	no	10,000	1.26	YES
Southeast-1	SW-046-MWS	Iron, Dissolved	µg/L	14,000	14,100		N/A	N/A	no	10,000	1.41	YES
Southeast-1	SW-046-MWS	Manganese	µg/L	430	11,500		N/A	N/A	no	1,000	11.5	YES

**Table 5**  
**10x Surface Water Criteria Exceedances**  
**Site-Wide Groundwater Study**

Discharge Area	Sample Location	Parameter	Unit	PAL Aqueous	Result	Flag	10x Organism Only (µg/L)	Factor of Exceedance	Exceeds 10x Organism Only	10x Salt Water Chronic	Factor of Exceedance	Exceeds 10x Salt Water Chronic
Southeast-1	SW-046-MWS	Manganese, Dissolved	µg/L	430	11,200	J	N/A	N/A	no	1,000	11.2	YES
Southeast-1	SW-046-MWS	Nickel	µg/L	390	100		46,000	0.002	no	82	1.22	YES
Southeast-1	SW-046-MWS	Nickel, Dissolved	µg/L	390	100		46,000	0.002	no	82	1.22	YES
Southeast-1	SW-047-MWS	Aluminum	µg/L	20,000	2,810		N/A	N/A	no	870	3.23	YES
Southeast-1	SW-047-MWS	Aluminum, Dissolved	µg/L	20,000	2,860		N/A	N/A	no	870	3.29	YES
Southeast-1	SW-047-MWS	Cobalt	µg/L	6	100		N/A	N/A	no	10	10.0	YES
Southeast-1	SW-047-MWS	Cobalt, Dissolved	µg/L	6	105		N/A	N/A	no	10	10.5	YES
Southeast-1	SW-047-MWS	Nickel	µg/L	390	99.4	J	46,000	0.002	no	82	1.21	YES
Southeast-1	SW-047-MWS	Nickel, Dissolved	µg/L	390	106	J	46,000	0.002	no	82	1.29	YES
Southeast-1/2	SW-042-MWS	Aluminum	µg/L	20,000	1,200		N/A	N/A	no	870	1.38	YES
Southeast-1/2	SW-042-MWS	Aluminum, Dissolved	µg/L	20,000	1,220		N/A	N/A	no	870	1.40	YES
Southeast-1/2	SW-042-MWS	Cobalt	µg/L	6	40.2		N/A	N/A	no	10	4.02	YES
Southeast-1/2	SW-042-MWS	Cobalt, Dissolved	µg/L	6	41.6		N/A	N/A	no	10	4.16	YES
Southeast-1/2	SW-043-MWS	Aluminum	µg/L	20,000	1,560		N/A	N/A	no	870	1.79	YES
Southeast-1/2	SW-043-MWS	Aluminum, Dissolved	µg/L	20,000	1,540		N/A	N/A	no	870	1.77	YES
Southeast-1/2	SW-043-MWS	Cobalt	µg/L	6	29.8		N/A	N/A	no	10	2.98	YES
Southeast-1/2	SW-043-MWS	Cobalt, Dissolved	µg/L	6	30.9		N/A	N/A	no	10	3.09	YES
Southeast-1/2	SW-043-MWS	Iron	µg/L	14,000	10,700		N/A	N/A	no	10,000	1.07	YES
Southeast-1/2	SW-043-MWS	Iron, Dissolved	µg/L	14,000	11,100		N/A	N/A	no	10,000	1.11	YES
Southeast-1/2	SW-043-MWS	Manganese	µg/L	430	1,070		N/A	N/A	no	1,000	1.07	YES
Southeast-1/2	SW-043-MWS	Manganese, Dissolved	µg/L	430	1,170	J	N/A	N/A	no	1,000	1.17	YES
Southeast-2	SG07-PDM008	Aluminum	µg/L	20,000	892		N/A	N/A	no	870	1.03	YES
Southeast-2	SG07-PDM008	Aluminum, Dissolved	µg/L	20,000	884		N/A	N/A	no	870	1.02	YES
Southeast-2	SW-040-MWS	Aluminum	µg/L	20,000	1,150	J	N/A	N/A	no	870	1.32	YES
Southeast-2	SW-041-MWS	Iron	µg/L	14,000	12,600		N/A	N/A	no	10,000	1.26	YES
Southeast-2	SW-041-MWS	Iron, Dissolved	µg/L	14,000	13,400		N/A	N/A	no	10,000	1.34	YES
Turning Basin	SW-030-MWS	Thallium, Dissolved	µg/L	2	4.8	J	4.7	1.02	YES	170	0.03	no
Turning Basin	SW-033-MWS	Aluminum	µg/L	20,000	881		N/A	N/A	no	870	1.01	YES

**Table 6**  
**Contaminant Mass Flux**

Coke Oven	Benz[a]anthracene	Benzene	Benzo[a]pyrene	Cyanide	Ethylbenzene	Naphthalene	Thallium	Thallium Dissolved	Toluene	Xylenes
Average Concentration (ug/L)	0.66	12,160.84	0.81	479.97	69.19	1,935.28	7.83	8.27	2,581.01	732.57
Discharge Rate (gal/day)	106,223	106,223	106,223	106,223	106,223	106,223	106,223	106,223	106,223	106,223
Mass Flux (g/day)	<b>0.27</b>	<b>4,890</b>	<b>0.33</b>	<b>193</b>	<b>27.8</b>	<b>778</b>	<b>3.15</b>	<b>3.32</b>	<b>1,038</b>	<b>295</b>

Coke Point-1	Aluminum	Aluminum Dissolved	Benz[a]anthracene	Naphthalene	Thallium	Thallium Dissolved	Xylenes
Average Concentration	-	-	1.00	117.21	0.11	0.08	8.21
Discharge Rate (gal/day)	536,857	536,857	536,857	536,857	536,857	536,857	536,857
Mass Flux (g/day)	-	-	<b>2.03</b>	<b>238</b>	<b>0.21</b>	<b>0.16</b>	<b>16.7</b>
Coke Point-2	Aluminum	Aluminum Dissolved	Benz[a]anthracene	Naphthalene	Thallium	Thallium Dissolved	Xylenes
Average Concentration	1740.00	1850.00	0.89	1,684.57	5.90	10.00	117.22
Discharge Rate (gal/day)	302,814	302,814	302,814	302,814	302,814	302,814	302,814
Mass Flux (g/day)	<b>1,995</b>	<b>2,121</b>	<b>1.02</b>	<b>1,931</b>	<b>6.76</b>	<b>11.5</b>	<b>134</b>

Turning Basin	Aluminum	Aluminum Dissolved	Cyanide	Thallium	Thallium Dissolved
Average Concentration	473.56	265.51	43.58	8.50	8.34
Discharge Rate (gal/day)	77,092	77,092	77,092	77,092	77,092
Mass Flux (g/day)	<b>138</b>	<b>77.5</b>	<b>12.7</b>	<b>2.48</b>	<b>2.43</b>

Southeast-3	Aluminum	Aluminum Dissolved	Cobalt	Cobalt Dissolved	Iron	Iron Dissolved	Manganese	Manganese Dissolved	Nickel	Nickel Dissolved
Average Concentration	-	121.75	-	5.00	-	45.50	-	2.06	-	7.43
Discharge Rate (gal/day)	64,708	64,708	64,708	64,708	64,708	64,708	64,708	64,708	64,708	64,708
Mass Flux (g/day)	-	<b>29.8</b>	-	<b>1.22</b>	-	<b>11.1</b>	-	<b>0.50</b>	-	<b>1.82</b>
Southeast-2	Aluminum	Aluminum Dissolved	Cobalt	Cobalt Dissolved	Iron	Iron Dissolved	Manganese	Manganese Dissolved	Nickel	Nickel Dissolved
Average Concentration	831.17	652.74	15.15	14.01	4832.17	4171.00	410.63	370.20	14.83	13.02
Discharge Rate (gal/day)	916,954	916,954	916,954	916,954	916,954	916,954	916,954	916,954	916,954	916,954
Mass Flux (g/day)	<b>2,885</b>	<b>2,266</b>	<b>52.6</b>	<b>48.6</b>	<b>16,773</b>	<b>14,478</b>	<b>1,425</b>	<b>1,285</b>	<b>51.5</b>	<b>45.2</b>
Southeast-1	Aluminum	Aluminum Dissolved	Cobalt	Cobalt Dissolved	Iron	Iron Dissolved	Manganese	Manganese Dissolved	Nickel	Nickel Dissolved
Average Concentration	894.88	816.51	58.15	59.08	11518.65	10610.05	2369.76	2,378.25	48.09	49.18
Discharge Rate (gal/day)	287,485	287,485	287,485	287,485	287,485	287,485	287,485	287,485	287,485	287,485
Mass Flux (g/day)	<b>974</b>	<b>889</b>	<b>63.3</b>	<b>64.3</b>	<b>12,535</b>	<b>11,546</b>	<b>2,579</b>	<b>2,588</b>	<b>52.3</b>	<b>53.5</b>

Northwest	Aluminum	Aluminum Dissolved	Arsenic	Arsenic Dissolved	Cobalt	Cobalt Dissolved	Cyanide	Iron	Iron Dissolved	Manganese	Manganese Dissolved
Average Concentration	357.31	551.71	13.47	5.84	41.24	4.50	210.61	5,348.08	225.64	241.31	124.09
Discharge Rate (gal/day)	318154	318,154	318154	318,154	318,154	318,154	318,154	318,154	318,154	318154	318,154
Mass Flux (g/day)	<b>430</b>	<b>664</b>	<b>16.2</b>	<b>7.04</b>	<b>49.7</b>	<b>5.42</b>	<b>254</b>	<b>6,441</b>	<b>272</b>	<b>291</b>	<b>149</b>
Northwest Cont.	Nickel	Nickel Dissolved									
Average Concentration	60.81	5.22									
Discharge Rate (gal/day)	318154	318,154									
Mass Flux (g/day)	<b>73.2</b>	<b>6.29</b>									

**Table 7**  
**Back River Effluent Outfall Discharges**

Month	Outfall #					
	Outfall 001		Outfall 012		Outfall 021	
Avg	Max	Avg	Max	Avg	Max	
January	9	9	19.6	24.3	21.4	25.9
February	9	9	20.5	43.8	23.7	72.4
March	9	9	18.5	21.2	21.2	42.4
April	9	9	16	20.1	22	26.7
May	16	16	15.9	23.2	22	26.7
June	16	16	17.8	22.4	12.7	19.4
July	16	16	18.8	23	11.5	11.5
August	16	16	18.8	23.5	11.5	11.5
September	16	16	17.4	23.7	11.5	23
October	16	16	19	22.9	11.5	11.5
November	16	16	19.4	27	11.5	11.5
December	16	16	25.3	33	11.5	11.5
<b>Min</b>	9	9	15.9	20.1	11.5	11.5
<b>Max</b>	16	16	25.3	43.8	23.7	72.4
<b>Average</b>	13.7	13.7	18.9	25.7	16	24.5

*All discharge values in millions of gallons per day*

**Table 8 - Estimate of Jones Creek and North Point Creek Discharge**

USGS Hydrologic Unit	Station Name	Period of Record	Drainage Area (mi2)	% Impervious	Mean Annual Flow (gpd)	Standardized Mean Annual Flow (gpd/mi2)
	Jones Creek Watershed		1.44	27		
	North Point Creek Watershed		0.90	16		
1585400	BRIEN RUN AT STEMMERS RUN, MD	1959-1986	1.97	45	1,680,307	852,948
1585105	HONEYGO RUN AT WHITE MARSH, MD	1990-1993	2.65		2,455,834	926,730
1585100	WHITEMARSH RUN AT WHITE MARSH, MD	1959-1988	7.61	31	8,401,536	1,104,013
1585300	STEMMERS RUN AT ROSSVILLE, MD	1959-1971	4.46	29	4,265,395	956,367
1585230	MOORES RUN AT RADECKE AVE AT BALTIMORE, MD	1997-2008	3.52		3,037,478	862,920
1585225	MOORES RUN TRIB. NEAR TODD AVE AT BALTIMORE, MD	1997-2008	0.21		180,956	861,696

Average Standardized Mean Annual Flow of Gaging Stations 927,445 gpd/mi2

Estimated Base Flow for Jones Creek 1,337,405 gpd

Estimated Base Flow for North Point Creek 834,701 gpd

mi2 = miles square

gpd = gallons per day

Sources:

Bear Creek/Old Road Bay

Small Watershed

Action Plan

**Table 9**  
**Surface Water Mixing Analysis**

Receiving Water Body		Constituents of Potential Concern (>10x Surface Water Criteria)	Ambient Surface Water Quality Criteria		Flow-Weighted Average Groundwater Well Concentration (ug/L)	Estimated Contaminant Mass Flux (g/day)	Estimated Surface Water Concentration (ug/L)	Exceeds Ambient Water Quality Criteria
			Organism Consumption (ug/L)	Saltwater Chronic Aquatic Life (ug/L)				
<b>Turning Basin</b>								
		TB						
			Aluminum Dissolved		87.000	265.51	77.5	0.73
Groundwater Flow	1,750	m <sup>3</sup> /d	Thallium Dissolved	0.470	17.000	8.34	2.4	0.02
Freshwater Base Flow	0	m <sup>3</sup> /d	Aluminum		87.000	473.56	138.2	1.30
			Thallium	0.470	17.000	8.50	2.5	0.02
<b>Jones Creek</b>								
		SE-1						
			Cobalt		1	58.15	63.3	0.57
Groundwater Flow	1,088	m <sup>3</sup> /d	Cobalt Dissolved		1	59.08	64.3	0.57
Freshwater Base Flow	5,063	m <sup>3</sup> /d	Manganese		100	2,369.76	2,578.9	22.33
			Manganese Dissolved		100	2,378.25	2,588.1	22.26
			Aluminum		87.000	894.88	973.8	10.94
			Aluminum Dissolved		87.000	816.51	888.6	9.59
			Iron		1000	11,518.65	12,535.2	119.09
			Iron Dissolved		1000	10,610.05	11,546.4	108.65
			Nickel	4600	8.2	48.09	52.3	0.48
			Nickel Dissolved	4600	8.2	49.18	53.5	0.48
<b>Old Road Bay</b>								
		SE-2						
			Cobalt		1	15.15	52.6	0.13
Groundwater Flow	3,471	m <sup>3</sup> /d	Cobalt Dissolved		1	14.01	48.6	0.13
Freshwater Base Flows			Manganese		100	410.63	1,425.3	4.47
North Point Creek	3,160	m <sup>3</sup> /d	Manganese Dissolved		100	370.20	1,285.0	4.33
Outfall 001	51,860	m <sup>3</sup> /d	Aluminum		87.000	831.17	2,885.0	4.31
			Aluminum Dissolved		87.000	652.74	2,265.7	3.53
			Iron		1000	4,832.17	16,772.7	32.75
			Iron Dissolved		1000	4,171.00	14,477.7	29.08
			Nickel	4600	8.2	14.83	51.5	0.12
			Nickel Dissolved	4600	8.2	13.02	45.2	0.11

Estimated Surface Water Concentration - See example calculations in Appendix D for aluminum in the Turning Basin and cobalt in Jones Creek and Old Road Bay.

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## **APPENDIX A**

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## MDE Well Database Search Results

COUNTY LETTER	PERMIT	B1 RECD	CITY	STATE	ZIP	APPROX_DEPTH	SUBDIVISION	NEAREST TOWN	TOWN_DISTANCE	ROAD_NAME	ROAD_SIDE	ROAD_DISTANCE	LAT_DEC_DEG	LON_DEC_DEG	TOTAL_DEPTH	ABANDONED	ABANDON_DATE		
AA	AA731735	7/24/1973	PASADENA	MD		60	GREEN GABLES	LAKE SHORE	4 MI	CHESAPEAKE PL	N	25 FT	39.232558	76.452504	56				
BA	BA700348	2/20/1970	BALTIMORE	MD		70	EDGEMERE	EDGEMERE	1 MI	SHORE RD	E	15 FT	39.232558	76.452504	85				
BA	BA710314	3/1/1971	BALTIMORE	MD		50		ESSEX	6 MI	RIVER VIEW RD	S	50 FT	39.246202	76.434744	46				
BA	BA720180	9/8/1971	BALTIMORE	MD		100		ESSEX	5 MI	BARRISON PT	W	75 FT	39.259929	76.434635	108				
BA	BA730151	9/7/1972	SPARROWS PT	MD		80		EDGEMERE	1 MI	SHORE RD LOT 6&7	E	25 FT	39.232638	76.470155	75				
BA	BA730405	1/8/1973	DUNDALK	MD		70		ESSEX	5 MI		S	125 FT	39.246202	76.434744	70				
BA	BA730626	3/30/1973	BALTIMORE	MD		70		ESSEX	5 MI	WILDWOOD BCH RD	S	25 FT	39.232474	76.434853	70				
BA	BA730912	7/27/1973	PERRY HALL	MD		60		ESSEX	5 MI	BEACHWOOD AVE	S	100 FT	39.246202	76.434744	70				
BA	BA730946	8/2/1973	ESSEX	MD		80		WHITE MARCH	MI	WHITE MARCH RD	N	30 FT	39.232717	76.487806	245				
BA	BA731627	8/1/1974	BALTIMORE	MD		110		EVERGREEN PARK	ESSEX	6 MI	BEACHWOOD RD OAK AVE	S	50 FT	39.246202	76.434744	51			
BA	BA732771	2/2/1976	BALTIMORE	MD		60	EVERGREEN PARK	EVERGREEN PK	6 MI	BEACHWOOD RD	S	50 FT	39.246202	76.434744	52				
BA	BA732894	3/18/1976	BALTIMORE	MD		60	EVERGREEN PK	EVERGREEN PK	0 MI	380B BEECHWOOD RD	W	30 FT	39.246285	76.452399					
BA	BA734016	1/21/1977	FULLERTON	MD		90		SPARROWS POINT	0 MI	GRAYS RD	E	300 FT	39.260247	76.505267					
BA	BA734478	5/25/1977	SPARROWS PT	MD		500		DUNDALK	0 MI	WILDWOOD BEACH RD	S	30 FT	39.259929	76.434635	60				
BA	BA734709	7/15/1977	MIDDLE RIVER	MD	21221	60		ESSEX	5 MI	EVERGREEN PARK	0 MI	1713 SEASIDE RD	S	20 FT	39.259929	76.434635	60		
BA	BA735195	11/22/1977	BALTIMORE	MD		100		DUNDALK	0 MI	DUNDALK	4 MI	SEASIDE RD	W	30 FT	39.254786	76.512368	45		
BA	BA735729	5/5/1978	DUNDALK	MD		60		DUNDALK	0 MI	SEASIDE RD	N	60 FT	39.260172	76.487609	45				
BA	BA735827	6/7/1978	DUNDALK	MD		50		SPARROWS POINT	0 MI	SPARROWS POINT	2 MI	SEASIDE RD	E	30 FT	39.232638	76.470155			
BA	BA736064	8/4/1978	BALTIMORE	MD		60	EVERGREEN PARK	EVERGREEN PARK	0 MI	SPARROWS POINT	2 MI	SEASIDE RD	E	100 FT	39.246202	76.434744	60		
BA	BA736533	3/15/1979	DUNDALK	MD		100		SPARROWS POINT	0 MI	SPARROWS POINT	5 MI	SEASIDE RD	N	500 FT	39.24652	76.505362	185		
BA	BA737085	10/2/1979	ESSEX	MD		70		SPARROWS POINT	0 MI	SPARROWS POINT	5 MI	SEASIDE RD	N	15 FT	39.260094	76.469951	85		
BA	BA737186	12/11/1979	BALTIMORE	MD		80	EVERGREEN PARK	EVERGREEN PARK	0 MI	SPARROWS POINT	2 MI	SEASIDE RD	E	20 FT	39.246202	76.434744	180		
BA	BA737198	12/26/1979	SPARROWS PT	MD		30		SPARROWS POINT	2 MI	SPARROWS POINT	2 MI	SEASIDE RD	E	35 FT	39.232638	76.470155			
BA	BA737199	12/26/1979	SPARROWS PT	MD		30		SPARROWS POINT	2 MI	SPARROWS POINT	2 MI	SEASIDE RD	E	150 FT	39.232638	76.470155			
BA	BA737200	12/26/1979	SPARROWS POINT	MD		30		SPARROWS POINT	2 MI	SPARROWS POINT	2 MI	SEASIDE RD	E	100 FT	39.232638	76.470155			
BA	BA737201	12/26/1979	SPARROWS POINT	MD		30		SPARROWS POINT	2 MI	SPARROWS POINT	2 MI	SEASIDE RD	E	35 FT	39.232638	76.470155			
BA	BA737202	12/26/1979	SPARROWS POINT	MD		25		SPARROWS POINT	2 MI	SPARROWS POINT	2 MI	SEASIDE RD	E	35 FT	39.232638	76.470155			
BA	BA737203	12/26/1979	SPARROWS POINT	MD		30		SPARROWS POINT	2 MI	SPARROWS POINT	2 MI	SEASIDE RD	E	70 FT	39.232638	76.470155			
BA	BA737327	3/18/1980	BALTIMORE	MD		50		ESSEX	5 MI	WILDWOOD BEACH RD	E	125 FT	39.246202	76.434744	30				
BA	BA737332	3/24/1980	DUNDALK	MD		100		DUNDALK	0 MI	SPARROWS POINT	0 MI	WILDWOOD BEACH RD	N	650 FT	39.24652	76.505362	182		
BA	BA737517	7/10/1980	BALTIMORE	MD		70		ESSEX	5 MI	SPARROWS POINT	0 MI	WILDWOOD BEACH RD	N	30 FT	39.259929	76.434635	105		
BA	BA810319	10/27/1981	SPARROWS PT	MD		55	BETHLEHEM STEEL PROP	SPARROWS POINT	1.5 MI	SPARROWS POINT	1.5 MI	PENINSULA EXPRESSWAY	N	1000 FT	39.246429	76.484177	53		
BA	BA810320	10/27/1981	SPARROWS PT	MD		90	BETHLEHEM STEEL CORP	SPARROWS POINT	1.5 MI	SPARROWS POINT	1.5 MI	PENINSULA EXPRESSWAY	N	700 FT	39.243668	76.480666	84	Y	6/19/2002
BA	BA810321	10/27/1981	SPARROWS PT	MD		60	BETHLEHEM STEEL CORP	SPARROWS POINT	1.5 MI	SPARROWS POINT	1.5 MI	BETHLEHEM BLVD	N	1500 FT	39.240938	76.484216	56	Y	6/19/2006
BA	BA810322	10/27/1981	SPARROWS PT	MD		40	BETHLEHEM STEEL CORP	SPARROWS POINT	1.5 MI	SPARROWS POINT	1.5 MI	BETHLEHEM BLVD	N	1100 FT	39.240969	76.491278	37		
BA	BA810323	10/27/1981	SPARROWS PT	MD		60	BETHLEHEM STEEL CORP	SPARROWS POINT	1.5 MI	SPARROWS POINT	1.5 MI	BETHLEHEM BLVD	N	400 FT	39.238208	76.487767	60	Y	6/19/2006
BA	BA810324	10/27/1981	SPARROWS PT	MD		30	BETHLEHEM STEEL CORP	SPARROWS POINT	1.5 MI	SPARROWS POINT	1.5 MI	BETHLEHEM BLVD	N	300 FT	39.238192	76.484236	26	Y	6/19/2006
BA	BA810325	10/27/1981	SPARROWS PT	MD		60	BETHLEHEM STEEL CORP	SPARROWS POINT	1.5 MI	SPARROWS POINT	1.5 MI	BETHLEHEM BLVD	N	300 FT	39.238192	76.484236	60		
BA	BA810326	10/27/1981	SPARROWS PT	MD		70	BETH STEEL CORP PROP	SPARROWS POINT	1 MI	SPARROWS POINT	1 MI	TIN MILL RD	N	1000 FT	39.227241	76.491376	70		
BA	BA810327	10/27/1981	SPARROWS PT	MD		100	BETH STEEL CORP PROP	SPARROWS POINT	1 MI	SPARROWS POINT	1 MI	TIN MILL RD	N	1000 FT	39.227241	76.491376	101		
BA	BA810328	10/27/1981	SPARROWS PT	MD		65	BETH STEEL CORP PROP	SPARROWS PT	1 MI	SPARROWS POINT	1 MI	TIN MILL RD	N	2400 FT	39.232701	76.484276	8	Y	7/13/1998
BA	BA810329	10/27/1981	SPARROWS PT	MD		10	BETH STEEL CORP PROP	SPARROWS PT	1 MI	SPARROWS POINT	1 MI	TIN MILL RD	N	2400 FT	39.232701	76.484276	63	Y	7/13/1998
BA	BA810330	10/27/1981	SPARROWS PT	MD		60	BETH STEEL CORP PROP	SPARROWS PT	1 MI	SPARROWS POINT	1 MI	TIN MILL RD	N	1200 FT	39.227195	76.480786	62		
BA	BA811431	4/5/1983	SPARROWS PT	MD	21218	20	SPARROWS POINT	SPARROWS POINT	0 MI	I-695	N	600 FT	39.238192	76.484236	19	Y	6/19/2006		
BA	BA811432	4/5/1983	SPARROWS PT	MD	21218	15	SPARROWS POINT	SPARROWS POINT	0 MI	I-695	N	1120 FT	39.240938</						

## MDE Well Database Search Results

COUNTY LETTER	PERMIT	B1 RECD	CITY	STATE	ZIP	APPROX_DEPTH	SUBDIVISION	NEAREST TOWN	TOWN_DISTANCE	ROAD_NAME	ROAD_SIDE	ROAD_DISTANCE	LAT_DEC_DEG	LON_DEC_DEG	TOTAL_DEPTH	ABANDONED	ABANDON_DATE
BA	BA814133	9/9/1985	BEAVER	PA	15009	10		SPARROWS POINT	0 MI	TIN MILL RD	E	1000FT	39.246444	76.487708	30		
BA	BA814134	9/9/1985	BEAVER	PA	15009	10		SPARROWS POINT	0 MI	TIN MILL RD	E	1000FT	39.246444	76.487708	30		
BA	BA814135	9/9/1985	BEAVER	PA	15009	30		SPARROWS POINT	0 MI	TIN MILL RD	E	1000FT	39.246444	76.487708	30		
BA	BA814136	9/9/1985	BEAVER	PA	15009	30		SPARROWS POINT	0 MI	TIN MILL RD	E	1000FT	39.246444	76.487708	10		
BA	BA814137	9/9/1985	BEAVER	PA	15009	30		SPARROWS POINT	0 MI	TIN MILL RD	E	1000FT	39.246444	76.487708	10		
BA	BA814138	9/9/1985	BEAVER	PA	15009	30	SPARROWS POINT	SPARROWS POINT	0 MI	TIN MILL RD	E	1000FT	39.246444	76.487708	10		
BA	BA814284	10/28/1985	SPARROWS PT	MD	21219	50		SPARROWS POINT	0 MI	BETHLEHEM BLVD	W	100 FT	39.257316	76.462908	45		
BA	BA814285	10/28/1985	SPARROWS PT	MD	21219	50		SPARROWS PT	0 MI	BETHLEHEM BLVD	W	100 FT	39.257316	76.462908	33		
BA	BA814430	11/25/1985	EDGEMERE	MD		30	EDGEMERE	EDGEMERE	1.2 MI	GRAYS RD	E	150 FT	39.249096	76.466502	23		
BA	BA814431	11/25/1985	EDGEMERE	MD		30	EDGEMERE	EDGEMERE	1.2 MI	GRAYS RD	E	175 FT	39.24635	76.466522	23		
BA	BA814432	11/25/1985	EDGEMERE	MD		30	EDGEMERE	EDGEMERE	1.2 MI	GRAYS RD	E	125 FT	39.24635	76.466522	23		
BA	BA814604	2/28/1986	SPARROWS POIN	MD	21222	22				TEN MILL RD	W		39.224449	76.480806			
BA	BA814605	2/28/1986	SPARROWS POIN	MD	21222	60	HUMPHEYS INPOUND MEN	SPARROWS POINT	1 MI	TEN MILL RD	W		39.224449	76.480806			
BA	BA814606	2/28/1986	SPARROWSPOINT	MD	21222	20				TEN MILL RD	W		39.22721	76.484316			
BA	BA814607	1/28/1986	SPARROWPOINT	MD	21222	60				TEN MILL RD	W		39.227179	76.477256			
BA	BA814608	1/28/1986	SPARROWPOINT	MD	21222	20				TEN MILL RD	W		39.221688	76.477297			
BA	BA814609	1/28/1986	SPARROWPOINT	MD	21222	600				TEN MILL RD	W		39.221688	76.477297			
BA	BA814610	1/28/1986	SPARROWPOINT	MD	21222	60	HUMPHEYSIMPOUNDMENT	SPARROWPOINT	1 MI	TEN MILL RD	W		39.224449	76.480806			
BA	BA814611	1/28/1986	SPARROWPOINT	MD	21222	20				TEN MILL RD	W		39.224449	76.480806			
BA	BA814612	1/28/1986	SPARROWPOINT	MD	21222	60	HUMPHEYS IMPOUNDMENT	SPARROWS PT	1 MI	TEN MILL RD	W		39.224465	76.484336			
BA	BA814613	1/28/1986	SPARROWPOINT	MD	21222	20	HUMPHEYS IMPOUNDMENT	SPARROWS POINT	1 MI	TEN MILL ROAD	W		39.224465	76.484336			
BA	BA814614	1/28/1986	SPARROWPOINT	MD	21222	20				TEN MILL RD	W		39.221688	76.477297			
BA	BA814615	1/28/1986	SPARROWPOINT	MD	21222	60	HUMPHEYS IMPOUNDMENT	SPARROWS POINT	1 MI	TEN MILL RD	W		39.221688	76.477297			
BA	BA814616	1/28/1986	SPARROWPOINT	MD	21222	60	HUMPHEYS IMPOUNDMENT	SPARROWS POINT	10 MI	TEN MILL RD	W		39.22721	76.484316			
BA	BA814617	1/28/1986	SPARROWPOINT	MD	21222	25	GRAYS LANDFILL	SPARROWS POINT	2.0 MI	PENNISULA EXP	W	600 FT	39.238161	76.477175			
BA	BA814618	1/28/1986	SPARROWPOINT	MD	21222	35	GRAYS LANDFILL	SPARROWS POINT	2 MI	PENNISULA EXP	W	600 FT	39.238161	76.477175			
BA	BA814628	1/28/1986	SPARROWPOINT	MD	21222	25	GRAYS LANDFILL	SPARROWS POINT	2 MI	PENNISULA EXP	W	600 FT	39.240922	76.480866			
BA	BA814629	1/28/1986	SPARROWPOINT	MD	21222	35	GRAYS LANDFILL	SPARROWS POINT	2 MI	PENNISULA EXP	W	600 FT	39.240922	76.480866			
BA	BA814630	1/28/1986	SPARROWPOINT	MD	21222	25	GRAYS ESTATE	SPARROWS POINT	2 MI	PENNISULA EXP	W	600 FT	39.238177	76.480706			
BA	BA814631	1/28/1986	SPARROWPOINT	MD	21222	35	GRAYS ESTATE	SPARROWS POINT	2 MI	PENNISULA EXP	W	600 FT	39.238177	76.480706			
BA	BA814632	1/28/1986	SPARROWPOINT	MD	21222	40	GRAYS LANDFILL	SPARROWS POINT	2 MI	PENNISULA EXP	W	600 FT	39.240938	76.484216			
BA	BA814633	1/28/1986	SPARROWPOINT	MD	21222	50	GRAYS LANDFILL	SPARROWS POINT RD	2 MI	PENNISULA EXP	W	600 FT	39.240938	76.484216			
BA	BA814634	1/28/1986	SPARROWPOINT	MD	21222	25	GRAYS LANDFILL	SPARROWS POINT	2 MI	PENNISULA EXP	W	600 FT	39.238192	76.484236			
BA	BA814635	1/28/1986	SPARROWPOINT	MD	21222	35	GRAYS LANDFILL	SPARROWS POINT	MI	PENNISULA EXP	N	600 FT	39.238192	76.484236			Y 6/19/2006
BA	BA814636	1/28/1986	SPARROWPOINT	MD	21222	50	GRAYS LANDFILL	SPARROWS POINT	2 MI	PENNISULA EXP	W	600 FT	39.240938	76.484216			
BA	BA814637	1/28/1986	SPARROWPOINT	MD	21222	60	GRAYS LANDFILL	SPARROWPOINT	2 MI	PENNISULA EXP	W	600 FT	39.240938	76.484216			
BA	BA814638	1/28/1986	SPARROWPOINT	MD	21222	25	GRAYS LANDFILL	SPARROWS POINT	2 MI	PENNISULA EXP	W	600 FT	39.246398	76.477115			Y 2/19/1998
BA	BA814639	1/28/1986	SPARROWPOINT	MD	21222	35	GRAYS LANDFILL	SPARROWSPOINT	2 MI	PENNISULA	W	600 FT	39.246444	76.487708			
BA	BA814640	1/28/1986	SPARROWPOINT	MD	21222	35	GRAYS LANDFILL	SPARROWS POINT RD	2 MI	PENNISULA EXP	W	600 FT	39.254665	76.484117			
BA	BA814648	2/14/1986	BALTIMORE	MD	21221	90	EVERGREEN PARK	DUNDALK	4.3 MI	KELLY-CASE LA	S	25 FT	39.257201	76.438188	60		
BA	BA814649	2/18/1986	BALTIMORE	MD	21221	90	EVERGREEN PARK	DUNDALK	4.3 MI	BEACHWOOD AVE	E	110 FT	39.254455	76.43821	208		
BA	BA814915	5/24/1986	BALTIMORE	MD	21222	70	EVERGREEN PARK	ESSEX	5 MI	BAYSIDE RD	N	175 FT	39.254472	76.441741	178		
BA	BA814975	4/26/1986	BEAVER	PA	15009	10		SPARROWS POINT	0 MI	N WIRE MILL RD	W	50 FT	39.238238	76.494828	15		
BA	BA814976	4/26/1986	BEAVER	PA	15009	30		SPARROWS POINT	0 MI	N WIRE MILL RD	W	50 FT	39.238238	76.494828	30		
BA	BA814977	4/26/1986	BEAVER	PA	15009	60		SPARROWS POINT	0 MI	N WIRE MILL RD	W	50 FT	39.238238	76.494828	60		
BA	BA814978	4/26/1986	BEAVER	PA	15009	60		SPARROWS POINT	0 MI	N WIRE MILL	W	50 FT	39.238238	76.494828	60		
BA	BA814979	4/26/1986	BEAVER	PA	15009	30		SPARROWS POINT	0 MI	N WIRE MILL RD	W	50 FT	39.238238	76.494828	30		
BA	BA814980	4/26/1986	BEAVER	PA	150												

## MDE Well Database Search Results

COUNTY LETTER	PERMIT	B1 RECD	CITY	STATE	ZIP	APPROX_DEPTH	SUBDIVISION	NEAREST TOWN	TOWN_DISTANCE	ROAD NAME	ROAD SIDE	ROAD_DISTANCE	LAT_DEC_DEG	LON_DEC_DEG	TOTAL_DEPTH	ABANDONED	ABANDON_DATE
BA	BA817654	12/30/1987	EDGEMERE	MD	21219	15		EDGEMERE	.3 MI	NORTH POINT RD	N	150 FT	39.240794	76.452441	18		
BA	BA817655	12/30/1987	EDGEMERE	MD	21219	15		EDGEMERE	.3 MI	NORTH POINT RD	N	150 FT	39.240794	76.452441	18		
BA	BA817934	3/11/1988	SPARROWS PT	MD	21219	10		SPARROWS POINT	1 MI	N WIRE MILL RD	S	25 FT	39.238268	76.501889	10		
BA	BA817935	3/11/1988	SPARROWS PT	MD	21219	10		SPARROWS PT	1 MI	N WIRE MILL RD	S	25 FT	39.238268	76.501889	10		
BA	BA817936	3/11/1988	SPARROWS PT	MD	21219	10		SPARROWS POINT	1.0 MI	NORTH WINE MILL RD	N	25 FT	39.238268	76.501889	10		
BA	BA817937	3/11/1988	SPARROWS PT	MD	21219	10		SPARROWS POINT	1.0 MI	N WIRE MILL RD	S	125 FT	39.238268	76.501889	10		
BA	BA817938	3/11/1988	SPARROWS PT	MD	21219	10		SPARROWS POINT	1.0 MI	N WIRE MILL RD	S	125 FT	39.238268	76.501889	10		
BA	BA817939	3/11/1988	SPARROWS PT	MD	21219	30		SPARROWS POINT	1.0 MI	RIVERSIDE DR	E	50 FT	39.235508	76.498378	30		
BA	BA818361	6/2/1988	BALTIMORE	MD	21221	60	EVERGREEN PARK	EDGEMERE	1.1 MI	BEACHWOOD AVE	W	40 FT	39.254455	76.43821	45		
BA	BA818719	8/18/1988	BALTIMORE	MD	21219	60		SPARROWS POINT	1 MI	WHITE AVE	S	10 FT	39.229745	76.438405	135		
BA	BA818769	8/31/1988	BALTIMORE	MD	21221	50	EVERGREEN PARK	ESSEX	4 MI	EVERGREEN LA	N	20 FT	39.254455	76.43821	65		
BA	BA803046	11/17/1988	SPARROWS PT	MD	21219	20		SPARROWS POINT	0 MI	PENINSULA EXPRESSWAY	N	1000FT	39.243668	76.480666	14		
BA	BA803047	11/17/1988	SPARROWS PT	MD	21219	20		SPARROWS POINT	0 MI	PENINSULA EXPRESSWAY	N	1200FT	39.246413	76.480646	18		
BA	BA805043	12/27/1988	BALTIMORE	MD	21219	30		EDGEMERE	0 MI	GRAYS RD	W	500 FT	39.251841	76.466481			
BA	BA805044	12/27/1988	BALTIMORE	MD	21219	60		EDGEMERE	0 MI	GRAYS RD	W	300 FT	39.235368	76.466605			
BA	BA805045	12/27/1988	BALTIMORE	MD	21219	60		EDGEMERE	0 MI	GRAYS RD	W	200 FT	39.251841	76.466481			
BA	BA808042	4/10/1989	DUNDALK	MD	21222	25		DUNDALK	0 MI	MERRITT BLVD	W	20 FT	39.257531	76.512349	32		
BA	BA808043	4/10/1989	DUNDALK	MD	21222	25		DUNDALK	0 MI	MERRITT BLVD	W	10 FT	39.257531	76.512349	42		
BA	BA808044	4/10/1989	DUNDALK	MD	21222	25		DUNDALK	0 MI	MERRITT BLVD	W	150 FT	39.257531	76.512349	33		
BA	BA808045	4/10/1989	DUNDALK	MD	21222	25		DUNDALK	0 MI	MERRITT BLVD	W	FT	39.257531	76.512349	33		
BA	BA881059	5/1/1989	DUNDALK	MD	30			DUNDALK	0 MI	NEW NORTH POINT RD	E	40 FT	39.265569	76.466378	30		
BA	BA881060	5/1/1989	DUNDALK	MD	30			DUNDALK	0 MI	NEW NORTH POINT RD	E	90 FT	39.265569	76.466378	30		
BA	BA881061	5/1/1989	DUNDALK	MD	30			DUNDALK	0 MI	NEW NORTH POINT RD	E	110 FT	39.265569	76.466378	30		
BA	BA881062	5/1/1989	DUNDALK	MD	30			DUNDALK	0 MI	NEW BATTLE GROVE RD	S	180 FT	39.265569	76.466378	28		
BA	BA881141	5/30/1989	DUNDALK	MD	30			DUNDALK	0 MI	BROENING	S	75 FT	39.221559	76.449059			
BA	BA881604	9/20/1989	PHILADELPHIA	MD	35	MAP 45 D4		DUNDALK	0 MI	NEW NORTH POINT RD	E	15 FT	39.265678	76.491101	25		
BA	BA881605	9/20/1989	PHILADELPHIA	PA	19103	35	MAP 45 D4	DUNDALK	0 MI	NEW NORTH POINT RD	N	15 FT	39.268424	76.491081	30		
BA	BA881606	9/20/1989	PHILADELPHIA	PA	19103	35	MAP 45 D-4	DUNDALK	0 MI	NEW NORTH POINT RD	N	60 FT	39.268424	76.491081	28		
BA	BA881607	9/20/1989	PHILADELPHIA	PA	19103	35	MAP 45 D-4	DUNDALK	0 MI	NEW NORTH POINT RD	N	40 FT	39.268424	76.491081	30		
BA	BA882278	4/3/1990	BALTIMORE	MD	21221	60	EVERGREEN PARK	ESSEX	5 MI	BAYSIDE ROAD	N	100 FT	39.254472	76.441741	50		
BA	BA883289	4/29/1991	BALTIMORE	MD	21222	15		EDGEMERE	1 MI	4070 OLD NORTH PT RD	E	40 FT	39.268298	76.462825	23		
BA	BA883290	4/26/1991	BALTIMORE	MD	21222	15		EDGEMERE	1 MI	4070 OLD N POINT RD	E	50 FT	39.271044	76.462805	40		
BA	BA883291	4/26/1991	BALTIMORE	MD	21222	15		EDGEMERE	1 MI	4070 OLD NORTH PT RD	E	35 FT	39.268282	76.459293	27		
BA	BA883638	8/30/1991	TIMONIUM	MD	21093	25		EDGEMERE	1 MI	4049 N POINT RD	W	20 FT	39.268314	76.466357	25		
BA	BA920405	1/30/1991	EDGEWOOD	MD	21040	100		EDGEMERE	2 MI	WHITE AVE	E	91 FT	39.235253	76.441892	140		
BA	BA920412	5/6/1992	BALTIMORE	MD	21221	60		ESSEX	5 MI	1806 BEACHWOOD RD	W	50 FT	39.254455	76.43821	68		
BA	BA920492	5/27/1992	SPARKS	MD	21152	60	EVERGREEN PARK	ESSEX	5 MI	1706 BEACHWOOD AVE	W	50 FT	39.257201	76.438188	55		
BC	BC880595	10/31/1989	BALTIMORE	MD	21224	15		BALTIMORE	0 MI	PORTAL STREET	E	60 FT	39.260247	76.505267	25		
BC	BC880596	10/31/1989	BALTIMORE	MD	21224	15		BALTIMORE	0 MI	PORTAL STREET	E	50 FT	39.260247	76.505267			
BC	BC880597	10/31/1989	BALTIMORE	MD	21224	15		BALTIMORE	0 MI	PORTAL STREET	N	150 FT	39.260247	76.505267	27		
BC	BC880857	7/3/1990	BALTIMORE	MD	21219	20		BALTIMORE	0 MI	NORTH POINT BLVD.	E	100 FT	39.246285	76.452399			
BC	BC880858	7/3/1990	BALTIMORE	MD	21219	20		BALTIMORE	0 MI	NORTH POINT BLVD.	E	120 FT	39.246285	76.452399			
BC	BC920709	6/1/1995	DUNDALK	MD	21222	35		DUNDALK	0	NORTH POINT BLVD.	W	90 FT	39.260094	76.469951	35		
BA	BA881644		SPARROWS PTN	MD	21219	20		SPARROWS POINT	1	2415 GRAYS ROAD	N	45 FT	39.251825	76.46295	Y	12/16/1997	
BA	BA881646	10/3/1989	SPARROWS PTN	MD	21219	20		SPARROWS POINT	1	2415 GRAYS RD	N	30 FT	39.246334	76.462991	Y	12/16/1997	
BA	BA881647	10/3/1989	SPARROWS PTN	MD	21219	20		SPARROWS POINT	1	2415 GRAYS RD	N	40 FT	39.249079	76.46297	Y	12/16/1997	
AA	AA888665	11/10/1992	TOWSON	MD	21204	40		RIVIERA BEACH	2	FT. SMALLWOOD ROAD	E	135 FT	39.210813	76.502081	32		
AA	AA888666	11/10/1992	TOWSON	MD	21204	25		RIVIERA BEACH	2</td								

## MDE Well Database Search Results

COUNTY LETTER	PERMIT	B1 RECD	CITY	STATE	ZIP	APPROX_DEPTH	SUBDIVISION	NEAREST TOWN	TOWN DISTANCE	ROAD NAME	ROAD SIDE	ROAD_DISTANCE	LAT_DEC_DEG	LON_DEC_DEG	TOTAL_DEPTH	ABANDONED	ABANDON_DATE
BA	BA882979	11/14/1990	BALTIMORE	MD		20		BALTIMORE	5	NORTH POINT BLVD.	E	200 FT	39.246285	76.452399	20		
BA	BA882980	11/14/1990	BALTIMORE	MD		20		BALTIMORE	5	NORTH POINT BLVD.	E	170 FT	39.246285	76.452399	20		
BA	BA882981	11/14/1990	BALTIMORE	MD		20		BALTIMORE	5	NORTH POINT BLVD.	E	400 FT	39.246269	76.448868	20		
BA	BA881395	7/26/1989	DUNDALK	MD		40		DUNDALK	0	MERRITT BLVD.	W	45 FT	39.230076	76.512537	34		
BA	BA881396	7/26/1989	DUNDALK	MD		40		DUNDALK	0	MERRITT BLVD.	W	30 FT	39.230076	76.512537	33		
BA	BA882982	11/13/1990	BALTIMORE	MD		20		BALTIMORE	5	NORTH POINT BLVD.	E	300 FT	39.249014	76.448846	20		
BA	BA883169	2/22/1991	DUNDALK	MD	21222	15		BALTIMORE	1	DUNDALK AVE	S	110 FT	39.218989	76.487905	15		
BA	BA883170	2/22/1991	DUNDALK	MD	21222	15		BALTIMORE	1	DUNDALK AVE	S	60 FT	39.218989	76.487905			
BA	BA883171	2/22/1991	DUNDALK	MD	21222	15		BALTIMORE	1	DUNDALK AVE	S	35 FT	39.218989	76.487905	15		
BA	BA883221	3/20/1991	SPARROWS POIN	MD	21219	10		SPARROWS POINT	0	WIRE MILL RD.	S	100 FT	39.24646	76.491238	20		
BA	BA883222	3/20/1991	SPARROWS POIN	MD	21219	10		SPARROWS POINT	0	WIRE MILL RD.	S	100 FT	39.24644	76.487708	10		
BA	BA883223	3/20/1991	SPARROWS POIN	MD	21219	10		SPARROWS POINT	0	WIRE MILL RD.	S	0 FT	39.243683	76.484197	10		
BA	BA883224	3/20/1991	SPARROWS POIN	MD	21219	10		SPARROWS POINT	0	WIRE MILL RD.	E	30 FT	39.249143	76.477095	10		
BA	BA883225	3/20/1991	SPARROWS POIN	MD	21219	10		SPARROWS POINT	0	WIRE MILL RD.	N	30 FT	39.254665	76.484117	10		
BA	BA883226	3/20/1991	SPARROWS POIN	MD	21219	10		SPARROWS POINT	0	WIRE MILL RD.	N	30 FT	39.254681	76.487648	10		
BA	BA883267	4/15/1991	SPARROWS POIN	MD	21219	20		EDGEMERE	2	4515 NORTHPOINT BLVD	W	900 FT	39.251809	76.459419	20		
BA	BA883704	10/21/1991	DUNDALK	MD		40		DUNDALK	0	MERRITT BLVD	W	50 FT	39.257517	76.508817	40		
BA	BA883822	11/18/1991	BALTIMORE	MD	21201	30		BALTIMORE	2	WISE AVE	N	30 FT	39.268346	76.473421	18		
BA	BA883823	11/18/1991	BALTIMORE	MD	21201	30		BALTIMORE	2	WISE AVE	N	60 FT	39.268346	76.473421	20		
BA	BA883874	11/22/1991	BALTIMORE	MD	21222	20		NORTH POINT	1	NORTH POINT BLVD	E	100 FT	39.268298	76.462825	20		
BA	BA883890	12/5/1991	GREENBELT	MD	20770	20	SOLLERS POINT	DUNDALK	1	RAMP B-DUNDALK AVE	S	10 FT	39.238298	76.50895	20		
BA	BA883891	12/5/1991	GREENBELT	MD	20770	20	SOLLERS POINT	DUNDALK	1	DUNDALK AVE	S	15 FT	39.238313	76.512481	20		
BA	BA883892	12/5/1991	GREENBELT	MD	20770	20	SOLLERS POINT	DUNDALK	1	MAIN ST	S	10 FT	39.238313	76.512481	20		
BA	BA884072	3/3/1993	BALTIMORE	MD	21219	25		EDGEMERE	0	5200 NORTH POINT BLV	E	25 FT	39.238065	76.455993	25		
BA	BA920005	1/7/1992	SPARROWS PT	MD	21219	20		EDGEMERE	0	RESEVOIR RD	E	225 FT	39.246285	76.452399	15		
BA	BA920006	1/7/1992	SPARROWS PT	MD	21219	20		EDGEMERE	0	RESEVOIR RD	E	750 FT	39.24354	76.45242	25		
BA	BA920007	1/7/1992	SPARROWS PT	MD	21219	20		EDGEMERE	0	RESEVOIR RD	E	100 FT	39.246285	76.452399	17		
BA	BA920008	1/7/1992	SPARROWS PT	MD	21219	20		EDGEMERE	0	RESEVOIR RD	E	575 FT	39.246285	76.452399	18		
BA	BA920009	1/7/1992	SPARROWS PON	MD	21219	20		EDGEMERE	0	RESEVOIR RD	E	575 FT	39.246285	76.452399	15		
BA	BA920057	1/17/1992	BALTIMORE	MD	21201	25		BALTIMORE	2	WISE AVE	N	150 FT	39.271092	76.473401	20		
BA	BA920058	1/17/1992	BALTIMORE	MD	21201	25		BALTIMORE	2	WISE AVE	N	50 FT	39.271092	76.473401	21		
BA	BA920059	1/17/1992	BALTIMORE	MD	21201	25		BALTIMORE	2	WISE AVE	N	20 FT	39.271092	76.473401	22		
BA	BA920201	2/26/1992	BALTIMORE	MD	21222	20		BALTIMORE	0	WISE AVE	S	2830FT	39.246469	76.4983	20		
BA	BA920202	2/26/1992	BALTIMORE	MD	21222	20		BALTIMORE	0	WISE AVE	S	2825FT	39.249235	76.498281	20		
BA	BA920203	2/26/1992	BALTIMORE	MD	21222	20		BALTIMORE	0	WISE AVE	S	2800FT	39.246469	76.4983	20		
BA	BA920204	2/26/1992	BALTIMORE	MD	21222	20		BALTIMORE	0	WISE AVE	S	1980FT	39.243729	76.494789	25		
BA	BA920205	2/26/1992	BALTIMORE	MD	21222	20		BALTIMORE	0	WISE AVE	S	2005FT	39.24646	76.491238	25		
BA	BA920206	2/26/1992	BALTIMORE	MD	21222	20		BALTIMORE	0	WISE AVE	S	2000FT	39.246475	76.494769	25		
BA	BA920222	3/4/1992	SPARROWS PON	MD	21219	35		SPARROWS POINT	0	TIN MILL ROAD	S	120 FT	39.210753	76.487965	32		
BA	BA920245	3/12/1992	DUNDALK	MD		40		DUNDALK	0	NORTH POINT BLVD	N	50 FT	39.268314	76.466357	30		
BA	BA930175	6/22/1993	SPARROWS PNT	MD	21219	20		SPARROWS POINT	0	PENINSULA EXP.	E	800 FT	39.243729	76.494789	13		
BA	BA930176	6/22/1993	SPARROWS PNT	MD	21219	20		SPARROWS POINT	0	PENINSULA EXPRESSWAY	N	225 FT	39.243729	76.494789	18		
BA	BA930178	6/22/1993	SPARROWS PNT	MD	21219	20		SPARROWS POINT	0	BETHLEHEM BLVD	S	1450FT	39.246475	76.494769	15		
BA	BA930179	6/22/1993	SPARROWS PNT	MD	21219	20		SPARROWS POINT	0	BETHLEHEM BLVD.	S	550 FT	39.243729	76.494789	15		
BA	BA930167	6/3/1993	DUNDALK	MD	21219	20		EDGEMERE	1	4801 NORTH POINT BLV	W	250 FT	39.246318	76.459496	23		
BA	BA930168	6/3/1993	DUNDALK	MD	21219	20		EDGEMERE	1	4801 NORTH POINT BLV	W	250 FT	39.246302	76.455929	25		
BA	BA930169	6/3/1993	DUNDALK	MD	21219	20		EDGEMERE	1	4801 NORTH POINT BLV	W	3000FT	39.249047	76.455908	25		
BA	BA930174	6/22/1993	SPARROWS PNT	MD	21219	20		SPARROWS POINT	0	PENINSULA EXPR.	N	400 FT	39.246475	76.494769	17	Y	6/19/2006
BA	BA																

## MDE Well Database Search Results

COUNTY LETTER	PERMIT	B1 RECD	CITY	STATE	ZIP	APPROX_DEPTH	SUBDIVISION	NEAREST TOWN	TOWN_DISTANCE	ROAD NAME	ROAD SIDE	ROAD_DISTANCE	LAT_DEC_DEG	LON_DEC_DEG	TOTAL_DEPTH	ABANDONED	ABANDON_DATE
BA	BA930425	10/5/1993	EDGEMERE	MD	21219	30		EDGEMERE		GREENHILL RD	E	40 FT	39.238049	76.452462	24		
BA	BA930422	10/5/1993	EDGEMERE	MD	21219	30		EDGEMERE		GREENHILL RD	E	40 FT	39.238049	76.452462	24		
BA	BA930423	10/5/1993	EDGEMERE	MD	21219	30		EDGEMERE		GREENHILL RD	E	60 FT	39.238049	76.452462	23		
BA	BA930424	10/5/1993	EDGEMERE	MD	21219	30		EDGEMERE		GREENHILL RD	E	140 FT	39.238049	76.452462	25		
BA	BA930420	10/5/1993	EDGEMERE	MD	21219	30		EDGEMERE		GREENHILL RD	E	100 FT	39.238049	76.452462	24		
BA	BA930421	10/5/1993	EDGEMERE	MD	21219	30		EDGEMERE		GREENHILL RD	E	80 FT	39.238049	76.452462	26		
AA	AA940445	5/3/1996	BALTIMORE	MD	21224	150	BRANDON SHORES	FOREMANS CORNER	1.5	KEMBO ROAD	S	100 FT	39.219079	76.509083	140	Y	11/17/2001
AA	AA940446	5/3/1996	BALTIMORE	MD	21224	150	BRANDON SHORES	FOREMANS CORNER	1	KEMBO ROAD	S	25 FT	39.219079	76.509083	147		
BA	BA940621	10/31/1994	BALTIMORE	MD	21222	6		EDGEMERE		GRAYS ROAD	W	50 FT	39.240811	76.455972	19	Y	12/16/1997
BA	BA940403	9/14/1994	BALTIMORE	MD	21222	30		EDGEMERE		GRAYS ROAD	N	5 FT	39.243556	76.45595	30	Y	12/16/1997
BA	BA940404	9/14/1994	BALTIMORE	MD	21222	30		EDGEMERE		GRAYS ROAD	N	5 FT	39.243556	76.45595	27	Y	12/16/1997
BA	BA940665	11/15/1994	BALTIMORE	MD	21201	45		BALTIMORE	6	TRAPPE ROAD	S	500 FT	39.268439	76.494613	20	Y	8/16/1999
BA	BA940170	4/25/1994	SPARROWS PTN	MD	21219	30		SPARROWS POINT		BETHLEHEM BLVD	E	200 FT	39.240907	76.477155	32		
BA	BA940171	4/25/1994	SPARROWS PTN	MD	21219	30		SPARROWS POINT		BETHLEHEM BLVD	E	100 FT	39.238177	76.480706	32		
BA	BA940346	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	60 FT	39.21902	76.494964	15		
BA	BA940347	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	360 FT	39.21902	76.494964	15		
BA	BA940348	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	340 FT	39.21902	76.494964	15		
BA	BA940343	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	340 FT	39.21902	76.494964	15		
BA	BA940344	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	360 FT	39.21902	76.494964	15		
BA	BA940345	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	260 FT	39.21902	76.494964	15		
BA	BA940341	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	120 FT	39.21904	76.491435	15		
BA	BA940342	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	380 FT	39.219035	76.498494			
BA	BA940337	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	200 FT	39.21904	76.491435	15		
BA	BA940338	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	240 FT	39.21904	76.491435	15		
BA	BA940339	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	300 FT	39.21904	76.491435	15		
BA	BA940340	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	300 FT	39.21902	76.494964	15		
BA	BA940336	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	180 FT	39.21902	76.494964	15		
BA	BA940334	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	240 FT	39.218989	76.487905	15		
BA	BA940335	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	240 FT	39.21902	76.494964	15		
BA	BA940331	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	280 FT	39.21902	76.494964	15		
BA	BA940332	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	160 FT	39.21902	76.494964	15		
BA	BA940333	8/15/1994	BALTIMORE	MD	21222	10		DUNDALK		PENNISULA EXPRESSWAY	N	380 FT	39.21902	76.494964	15		
BA	BA940865	3/10/1995	DUNDALK	MD	21222	30		DUNDALK		NORTH POINT BLVD	W	65 FT	39.265553	76.462846	34		
BA	BA940862	3/8/1995	DUNDALK	MD	21222	30		DUNDALK		NORTH POINT BLVD	W	75 FT	39.268314	76.466357	35		
BA	BA940863	3/10/1995	DUNDALK	MD	21222	30		DUNDALK		NORTH POINT BLVD	W	90 FT	39.268298	76.462825	32		
BA	BA940864	3/10/1993	DUNDALK	MD	21222	30		DUNDALK		NORTH POINT BLVD	W	90 FT	39.265553	76.462846	35		
BA	BA940860	3/8/1995	DUNDALK	MD	21222	30		DUNDALK		NORTH POINT BLVD	W	120 FT	39.268314	76.466357	35		
BA	BA940861	3/8/1995	DUNDALK	MD	21222	30		DUNDALK		NORTH POINT BLVD	W	120 FT	39.268314	76.466357	35		
BA	BA941277	9/26/1995	BALTIMORE	MD	21221	60	EVERGREEN PARK	ESSEX	3	BEECHWOOD AVE	W	61 FT	39.254455	76.43821	206		
BA	BA941271	9/25/1995	BALTIMORE	MD	21222	30		BALTIMORE		NORTH POINT BLVD	W	75 FT	39.271044	76.462805	35		
BA	BA941272	9/25/1995	BALTIMORE	MD	21222	30		BALTIMORE		NORTH POINT BLVD	W	90 FT	39.271044	76.462805	37		
BA	BA941678	5/6/1996	SPARROWS PTN	MD	21219	15		SPARROWS POINT		YARD RD	W	20 FT	39.227099	76.459607	14	Y	5/9/1996
BA	BA941677	5/6/1996	SPARROWS PTN	MD	21219	15		SPARROW POINT		YARD RD	W	20 FT	39.227083	76.456077	14	Y	5/9/1996
BA	BA941025	6/9/1995	BALTIMORE	MD	21222	15		EDGEMERE	1	MORSE LA	N	900 FT	39.254522	76.452335			
BA	BA941026	6/9/1995	BALTIMORE	MD	21222	15		EDGEMERE	1	MORSE LA	N	550 FT	39.254522	76.452335			
BA	BA941027	6/9/1995	BALTIMORE	MD	21223	15		EDGEMERE	1	MORSE LA	N	350 FT	39.254505	76.448804			
BA	BA941028	6/9/1995	BALTIMORE	MD	21223	15		EDGEMERE	1	MORSE LA	N	200 FT	39.240744	76.441849			
BA	BA941029	6/9/1995	BALTIMORE	MD	21223	15		EDGEMERE	1	MORSE LA	N	400 FT	39.240778	76.44891			
BA	BA941030	6/9/1995															

## MDE Well Database Search Results

COUNTY LETTER	PERMIT	B1 RECD	CITY	STATE	ZIP	APPROX_DEPTH	SUBDIVISION	NEAREST TOWN	TOWN_DISTANCE	ROAD_NAME	ROAD_SIDE	ROAD_DISTANCE	LAT_DEC_DEG	LON_DEC_DEG	TOTAL_DEPTH	ABANDONED	ABANDON_DATE
BA	BA944674	10/17/2000	BALTIMORE	MD	21202	10		EDGEMERE		I-695	W	80 FT	39.243572	76.459481	18		
BA	BA944675	10/17/2000	BALTIMORE	MD	21202	10		EDGEMERE		I-695	E	20 FT	39.243556	76.45595	13		
BA	BA944676	10/17/2000	BALTO	MD	21202	15		EDGEMERE		I-695	E	20 FT	39.23259	76.459565	14		
BA	BA944677	10/17/2000	BALTO	MD	21202	55		EDGEMERE		I-695		20 FT	39.240827	76.459502	52		
BA	BA944678	10/17/2000	BALTO	MD	21202	20		EDGEMERE		I-695	E	20 FT	39.240811	76.455972	15		
BA	BA944679	10/17/2000	BALTIMORE	MD	21202	20		EDGEMERE		I-695	E	20 FT	39.240827	76.459502	20		
BA	BA944680	10/17/2000	BALTIMORE	MD	21202	15		EDGEMERE		I-695	E	25 FT	39.240827	76.459502	34		
BA	BA944681	10/17/2000	BALTIMORE	MD	21202	60		EDGEMERE		I-695	E	25 FT	39.240811	76.455972	55		
BA	BA942750	8/1/1997	EDGEMERE	MD	21219	20		EDGEMERE	0	NORTH POINT RD	E	81 FT	39.246218	76.438275			
BA	BA942991	10/23/1997	DUNDALK	MD	21222	35		DUNDALK	0	NORTH POINT RD			39.271169	76.491062			
BA	BA942992	10/24/1997	DUNDALK	MD	21222	35		DUNDALK	0	NORTH POINT	W	50 FT	39.268424	76.491081			
BA	BA942993	10/24/1997	DUNDALK	MD	21222	35		DUNDALK	0	NORTH POINT	W		39.268424	76.491081			
BA	BA946185	1/28/2002	BALTIMORE	MD	21222	15		SPARROWS POINT		919 WISE AVE	S	4000FT	39.246382	76.473584	22		
BA	BA945910	10/18/2001	BALTIMORE	MD	21222	20		NORTHPOINT		LYNHURST	W	300 FT	39.268249	76.452229	14		
BA	BA945911	10/18/2001	BALTIMORE	MD	21222	20		NORTHPOINT		LYNHURST	W	350 FT	39.268249	76.452229	13		
BA	BA945912	10/18/2001	BALTIMORE	MD	21222	20		NORTHPOINT		LYNHURST	W	450 FT	39.268249	76.452229	20		
BA	BA945913	10/18/2001	BALTIMORE	MD	21222	20		NORTHPOINT		LYNHURST	W	500 FT	39.268249	76.452229	25		
BA	BA945914	10/18/2001	BALTIMORE	MD	21222	20		NORTHPOINT		LYNHURST	W	525 FT	39.268249	76.452229	20		
BA	BA945813	9/18/2001	BALTIMORE	MD	21208	30		EDGEMERE		N POINT RD	E	40 FT	39.246252	76.445337	20		
BA	BA945814	9/18/2001	BALTIMORE	MD	21208	30		EDGEMERE		N POINT RD	E	40 FT	39.246252	76.445337	20		
BA	BA945815	9/18/2001	BALTIMORE	MD	21208	30		EDGEMERE		N POINT RD	E	50 FT	39.246252	76.445337	20		
BA	BA945712	8/21/2001	SPARROWS PON	MD	21219	60		SPARROWS POINT		I 695	S	560 FT	39.22448	76.487866	75		
BA	BA945701	8/21/2001	SPARROWS PON	MD	21219	12		SPARROWS POINT		I 695	S	520 FT	39.22175	76.491415	14		
BA	BA945702	8/21/2001	SPARROWS PON	MD	21219	12		SPARROWS POINT		I 695	S	560 FT	39.224496	76.491396	14		
BA	BA945703	8/21/2001	SPARROWS PON	MD	21219	12		SPARROWS POINT		I 695	S	600 FT	39.22448	76.487866	14		
BA	BA945704	8/21/2001	SPARROWS PON	MD	21219	12		SPARROWS POINT		I 695	S	570 FT	39.21902	76.494964	14		
BA	BA945705	8/21/2001	SPARROWS PON	MD	21219	30		SPARROWS POINT		I 695	S	840 FT	39.21902	76.494964	33		
BA	BA945706	8/21/2001	SPARROWS PON	MD	21219	30		SPARROWS POINT		I 695	S	1040FT	39.21902	76.494964	33		
BA	BA945707	8/21/2001	SPARROWS PON	MD	21219	30		SPARROWS POINT		I 695	S	700 FT	39.22175	76.491415	30		
BA	BA945708	8/21/2001	SPARROWS PON	MD	21219	30		SPARROWS POINT		I 695	S	360 FT	39.221735	76.487866	30		
BA	BA945709	8/21/2001	SPARROWS PON	MD	21219	30		SPARROWS POINT		I 695	S	585 FT	39.221735	76.487866	30		
BA	BA945710	8/21/2001	SPARROWS PON	MD	21219	30		SPARROWS POINT		I 695	S	785 FT	39.221735	76.487866	30		
BA	BA945711	8/21/2001	SPARROWS PON	MD	21219	12		SPARROWS POINT		I 695	S	440 FT	39.22448	76.487866	14		
BA	BA945620	6/27/2001	BALTIMORE	MD	21202			EDGEMERE		I-695	W	15 FT	39.254505	76.448804	30		
BA	BA945621	6/27/2001	BALTIMORE	MD	21202			EDGEMERE		I-695	W	70 FT	39.257267	76.452314	16		
BA	BA945610	6/27/2001	BALTIMORE	MD	21202			EDGEMERE		I-695	E	25 FT	39.246285	76.452399	36		
BA	BA945611	6/27/2001	BALTIMORE	MD	21202			EDGEMERE		I-695		30 FT	39.249063	76.459439	32		
BA	BA945612	6/27/2001	BALTIMORE	MD	21202			EDGEMERE		I-695		30 FT	39.246285	76.452399	30		
BA	BA945613	6/27/2001	BALTIMORE	MD	21202			EDGEMERE		I-695	E	15 FT	39.249047	76.455908	18		
BA	BA945614	6/27/2001	BALTIMORE	MD	21202			EDGEMERE		I-695	E	15 FT	39.246269	76.448868	36		
BA	BA945615	6/27/2001	BALTIMORE	MD	21202			EDGEMERE		I-695		20 FT	39.249031	76.452377	17		
BA	BA945616	6/27/2001	BALTIMORE	MD	21202			EDGEMERE		I-695		20 FT	39.25176	76.448825	32		
BA	BA945617	6/27/2001	BALTIMORE	MD	21202			EDGEMERE		I-695		20 FT	39.254522	76.452335	21		
BA	BA945618	6/27/2001	BALTIMORE	MD	21202			EDGEMERE		I-695		20 FT	39.254522	76.452335	39		
BA	BA945619	6/27/2001	BALTIMORE	MD	21202			EDGEMERE		I-695	W	10 FT	39.254505	76.448804	13		
BA	BA945412	3/16/2001	SPARROWS PON	MD	21219	32		SPARROWS POINT		RIVERSIDE DRIVE	E	75 FT	39.240969	76.491278	32		
BA	BA945228	11/8/2000	BALTIMORE	MD	21221	100	EVERGREEN PARK	ESSEX	2	BEACHWOOD AVE	W	75 FT	39.254455	76.43821	181		
BA	BA946781	7/23/2002	DUNDALK	MD		35		DUNDALK		NORTHPOINT BLVD	W	35 FT	39.268282	76.459293	30		
BA	BA946782	7/23/2002	DUNDALK	MD		35		DUNDALK		N POINT BLVD	W	115 FT	39.268249	76.452229	30		
BA																	

## MDE Well Database Search Results

COUNTY LETTER	PERMIT	B1 RECD	CITY	STATE	ZIP	APPROX_DEPTH	SUBDIVISION	NEAREST TOWN	TOWN_DISTANCE	ROAD NAME	ROAD SIDE	ROAD_DISTANCE	LAT_DEC_DEG	LON_DEC_DEG	TOTAL_DEPTH	ABANDONED	ABANDON_DATE
	BA950069	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	925 FT	39.254711	76.494711	16		
	BA950070	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	950 FT	39.254726	76.498242	15		
	BA950071	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	450 FT	39.254726	76.498242	14		
	BA950072	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	1100FT	39.254711	76.494711	15		
	BA950073	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	1300FT	39.254726	76.498242	14		
	BA950074	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	750 FT	39.254726	76.498242	16		
	BA950075	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	950 FT	39.254726	76.498242	14		
	BA950076	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	850 FT	39.254726	76.498242	15		
	BA950077	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	1250FT	39.254711	76.494711	20		
	BA950078	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	1700FT	39.254726	76.498242	14		
	BA950079	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	1600FT	39.254726	76.498242	14		
	BA950080	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	250 FT	39.254726	76.498242	15		
	BA950081	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	450 FT	39.254726	76.498242	11	Y	11/2/2010
	BA950082	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	400 FT	39.254726	76.498242	14		
	BA950083	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	925 FT	39.254726	76.498242	14		
	BA950084	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	900 FT	39.254726	76.498242	15		
	BA950085	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	1975FT	39.254726	76.498242	56		
	BA950086	2/15/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD ROAD	W	1350FT	39.254711	76.494711	26		
	BA950162	4/12/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD RD	W	1050FT	39.254726	76.498242	14	Y	9/15/2005
	BA950163	4/12/2005	SPARROWS POIN	MD	21219	15		SPARROWS POINT		SHIPPYARD RD	W	825 FT	39.254726	76.498242	14		
	BA950164	4/12/2005	SPARROWS PT	MD	21219	15		SPARROWS POINT		SHIPPYARD RD	W	875 FT	39.254726	76.498242	14		
	BA950165	4/12/2005	SPARROWS PT	MD	21219	15		SPARROWS POINT		SHIPPYARD RD	W	675 FT	39.254726	76.498242	15		
	BA950166	4/12/2005	SPARROWS PT	MD	21219	15		SPARROWS POINT		SHIPPYARD RD	W	675 FT	39.254726	76.498242	16		
BA	BA950065	2/15/2005	SPARROWS POINT	MD	21219	15		SPARROWS POINT	0	SHIPPYARD ROAD	W	400 FT	39.254726	76.498242	15		
BA	BA950066	2/15/2005	SPARROWS POINT	MD	21219	15		SPARROWS POINT	0	SHIPPYARD ROAD	W	500 FT	39.254726	76.498242	16		
BA	BA950188	4/29/2005	BALTIMORE	MD	21226	25		SOLLERS POINT		4100 BROENING HIGHWA	W	1000FT	39.243789	76.508912	8		
BA	BA950156	4/8/2005	BALTIMORE	MD	21221	100	EVERGREEN PARK	BALTIMORE	3	1222 BAYSIDE RD	N	15 FT	39.254455	76.43821	68		
BA	BA950442	6/16/2005	WESTMINSTER	MD	21157	100	EVERGREEN PARK	BALTIMORE	3	1205 BAYSIDE RD	S	15 FT	39.254455	76.43821	75		
BA	BA882128	2/15/1990	PHILADELPHIA	PA	19103	30		DUNDALK MARYLAND		NEW NORTH POINT ROAD	E	30 FT	39.265504	76.452251			
BA	BA882129	2/15/1990	PHILADELPHIA	PA	19103	30		DUNDALK MARYLAND		NEW NORTH POINT ROAD	E	20 FT	39.270995	76.452208			
BA	BA882130	2/15/1990	PHILADELPHIA	PA	19103	30		DUNDALK MARYLAND		NEW NORTH POINT ROAD	E	20 FT	39.268249	76.452229			
BA	BA882131	2/15/1990	PHILADELPHIA	PA	19103	30		DUNDALK MARYLAND		NEW NORTH POINT ROAD	E	20 FT	39.268266	76.455761			
	BA951240	4/10/2006	TIMONIUM	MD	21093	15		DUNDALK		8315 STANSBURY RD	S	60 FT	39.25738	76.477034	14	Y	3/3/2008
	BA951241	4/10/2006	TIMONIUM	MD	21093	15		DUNDALK		8315 STANSBURY RD	S	120 FT	39.25738	76.477034	13	Y	3/3/2008
	BA951242	4/10/2006	TIMONIUM	MD	21093	15		DUNDALK		8315 STANSBURY RD	S	170 FT	39.25738	76.477034	13	Y	3/3/2008
	BA951243	4/10/2006	TIMONIUM	MD	21093	15		DUNDALK		8315 STANSBURY RD	S	60 FT	39.25738	76.477034	13	Y	3/3/2008
	BA951244	4/10/2006	TIMONIUM	MD	21093	15		DUNDALK		8315 STANSBURY RD	S	180 FT	39.25738	76.477034	13	Y	3/3/2008
	BA951245	4/10/2006	TIMONIUM	MD	21093	15		DUNDALK		8315 STANSBURY RD	S	240 FT	39.25738	76.477034	13	Y	3/3/2008
	BA951246	4/10/2006	TIMONIUM	MD	21093	15		DUNDALK		8315 STANSBURY RD	S	240 FT	39.25738	76.477034	13	Y	3/3/2008
	BA951638	11/15/2006	SPARROWS POIN	MD	21219	300		SPARROWS POINT	2	BRANAN AVENUE	S	70 FT	39.227083	76.456077	300		
	BA951960	7/26/2007	SPARROWS PT	MD	21219	15	SPARROWS PT SHIPYARD	SPARROWS POINT		SHIPYARD ROAD	W	1500FT	39.271169	76.491062	17		
	BA951972	7/26/2007	SPARROWS PT	MD	21219	15	SPARROWS PT SHIPYARD	SPARROWS POINT		SHIPYARD RD	W	1500FT	39.271123	76.480465	12		
BA	BA952231	11/6/2007	DUNDALK	MD	21222	30	SITE 4049 NORTH PON	DUNDALK	2	ST GREGORY LANE	N	90 FT	39.270945	76.441612	30		
BA	BA952483	5/21/2008	SPARROWS POIN	MD	21219	20	GREYS LANDFILL	SPARROWS POINT	1	I695		300 FT	39.246444	76.487708	52		
BA	BA952484	5/21/2008	SPARROWS POIN	MD	21219	50	GREYS LANDFILL	SPARROWS POINT	1	I695	N	300 FT	39.246444	76.487708	15		
BA	BA952485	5/21/2008	SPARROWS POIN	MD	21219	20		SPARROWS POINT	1	I695	N	300 FT	39.246444	76.487708	17		
BA	BA952490	6/30/2008	BALTIMORE	MD	21222	266	BEACHWOOD NORTH	BALTIMORE	2	4219 RIVERSEDGE WAY	E	40 FT	39.265504				

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## **APPENDIX B**

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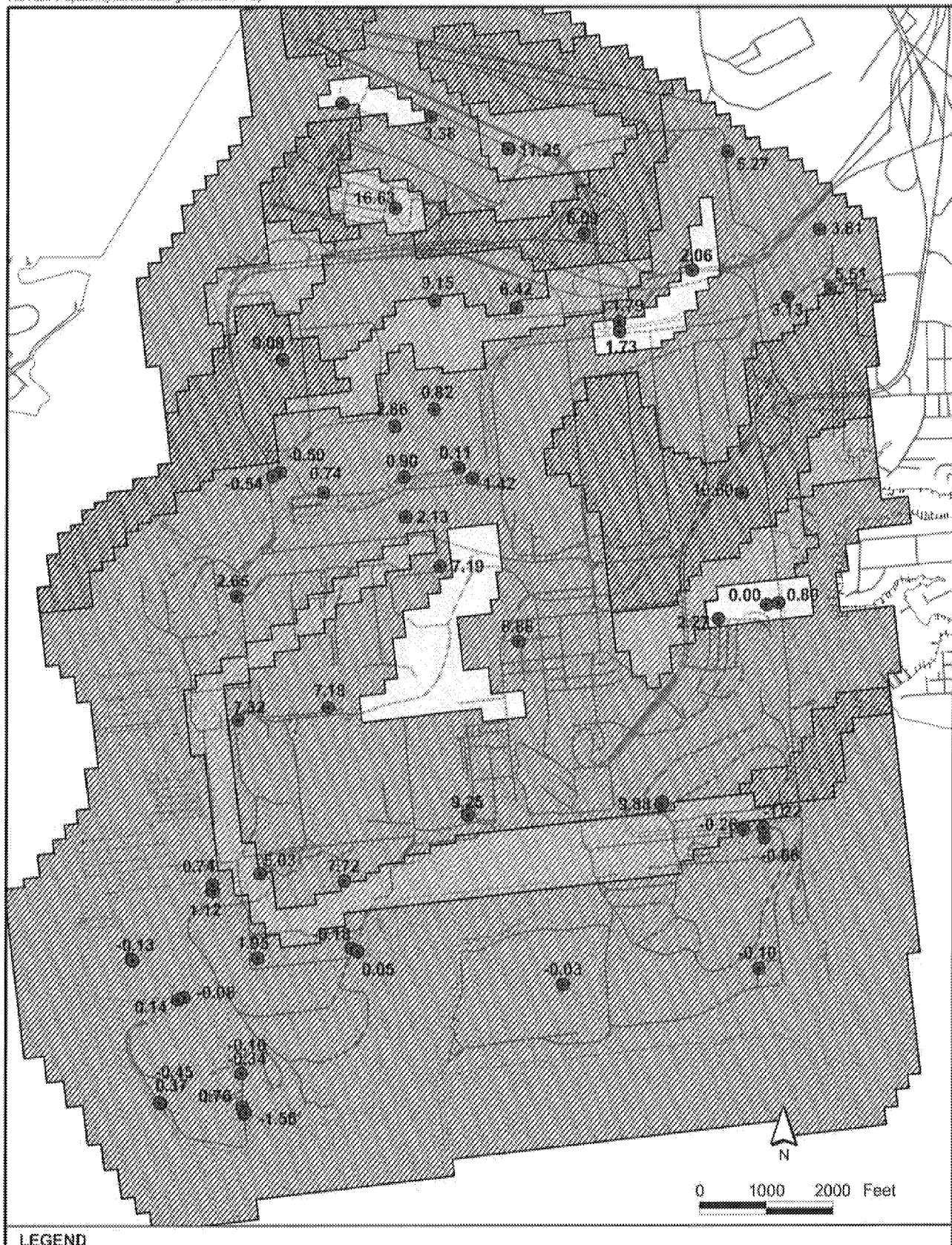


Figure 4.1-4  
Calibrated Hydraulic Conductivity of Layer 1

Bethlehem Steel Corp. - Sparrows Point Facility

CH2MHILL



LEGEND

- $\checkmark$  0.025 ft/day
- $\checkmark$  0.561 ft/day
- Water Bodies
- $\checkmark$  Roads

Figure 4.1-5  
Calibrated Hydraulic Conductivity of Layer 2

Bethlehem Steel Corp. - Sparrows Point Facility

**CH2MHILL**

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## **APPENDIX C**

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**Appendix C**  
**South Eastern 1 Discharge section**

EQUATION 1: CALCULATION OF CONDUCTIVITY

	Slag (MODEL LAYER 1)						Clay 1 (MODEL LAYER 2)			
	SE 1	black	red	yellow	blue	Totals	SE 1	black	red	Totals
	Segments (ft)	6011	385	1816	600	990		6011	238	5773
			63		680					
			863		614					
Length (ft)	6011	385	2742	600	2284	6011	6011	238	5773	6011
Percent Length (%)	100	0.06	0.46	0.10	0.38	1.00	100	0.04	0.96	1.00
Value (ft/day)		0.561	149	1200	20			0.025	0.561	
Percent Value (ft/day)		0.04	67.97	119.78	7.60	195.38		0.00	0.54	0.54

EQUATION 2: DISCHARGE RATE

	Section	length (ft)	k (ft/day)	Average thickness (ft)	Hydr. Grad.	Q (gal/day)
Slag Layer (Model Layer 1)	SE-1	6011	195.38	2.62	0.009666	222380.93
Clay 1 (Model Layer 2)			0.54	2.22		520.51
Sand 1 (Model Layer 3)			47	3.16		64584.02

SE-1 Total    287485.46

EQUATION 3: CONTAMINANT MASS FLUX

Section	Q (gal/day)	Parameter	Average Conc (ug/gal)	Mass Flux (g/day)
100x				
SE-1	287,485	Cobalt	220.12	63.3
		Cobalt (diss)	223.62	64.3
		Manganese	8,970.52	2,579
		Mn (diss)	9,002.65	2,588
10x				
SE-1	287,485	Aluminum	3,387.47	974
		Aluminum (diss)	3,090.83	889
		Iron	43,602.81	12,535
		Iron (diss)	40,163.39	11,546
		Nickel	182.03	52.3
		Nickel (diss)	186.15	53.5

**Appendix C**  
**South Eastern 2 Discharge section**

EQUATION 1: CALCULATION OF CONDUCTIVITY

	Slag (MODEL LAYER 1)				Clay 1 (MODEL LAYER 2)			
	SE 2	black	red	Totals	SE 2	black	red	Totals
Segments (ft)	6345	1049	501		6345	4466	1879	
			4795					
Length (ft)	6345	1049	5296	6345	6345	4466	1879	6345
Percent Length (%)	100	0.17	0.83	1.00	100	0.70	0.30	1.00
Value (ft/day)		0.561	149			0.025	0.561	
Percent Value (ft/day)		0.09	124.37	<b>124.46</b>		0.02	0.17	<b>0.18</b>

EQUATION 2: DISCHARGE RATE

	Section	length (ft)	k (ft/day)	Average thickness (ft)	Hydr. Grad.	Q (gal/day)
Slag Layer (Model Layer 1)	SE-2	6345	124.46	7.60	0.018090	811960.26
Clay 1 (Model Layer 2)			0.18	2.17		341.79
Sand 1 (Model Layer 3)			47	2.59		104651.69

**SE-2 Total    916953.74**

EQUATION 3: CONTAMINANT MASS FLUX

Section	Q (gal/day)	Parameter	Average Conc (ug/gal)	Mass Flux (g/day)
100x				
SE-2	916,954	Cobalt	57.35	<b>52.6</b>
		Cobalt (diss)	53.05	<b>48.6</b>
		Manganese	1,554.42	<b>1,425</b>
		Mn (diss)	1,401.36	<b>1,285</b>
10x				
SE-2	916,954	Aluminum	3,146.31	<b>2,885</b>
		Aluminum (diss)	2,470.90	<b>2,266</b>
		Iron	18,291.73	<b>16,773</b>
		Iron (diss)	15,788.95	<b>14,478</b>
		Nickel	56.14	<b>51.5</b>
		Nickel (diss)	49.28	<b>45.2</b>

**Appendix C**  
**South Eastern 3 Discharge section**

EQUATION 1: DISCHARGE RATE

Section	length (ft)	k (ft/day)	Average thickness (ft)	Hydr. Grad.	Q (gal/day)
Slag Layer (Model Layer 1)	SE-3	6351	149	0.001714	59896.52
Clay 1 (Model Layer 2)			0.561		28.55
Sand 1 (Model Layer 3)			47		4783.17

SE-3 Total    **64708.24**

EQUATION 2: CONTAMINANT MASS FLUX

Section	Q (gal/day)	Parameter	Average Conc (ug/gal)	Mass Flux (g/day)
100x				
SE-3	64,708	Cobalt	-	-
		Cobalt (diss)	18.93	<b>1.22</b>
		Manganese	-	-
		Mn (diss)	7.80	<b>0.50</b>
10x				
SE-3	64,708	Aluminum	-	-
		Aluminum (diss)	460.87	<b>29.8</b>
		Iron	-	-
		Iron (diss)	172.24	<b>11.1</b>
		Nickel	-	-
		Nickel (diss)	28.11	<b>1.82</b>

**Appendix C**  
**Turning Basin Discharge section**

EQUATION 1: CALCULATION OF CONDUCTIVITY

	Slag LAYER 1			
	TB	red	blue	Totals
Segments (ft)	6769	285	2688	
		3796		
Length (ft)	6769	4081	2688	6769
Percent Length (%)	100	0.60	0.40	1.00
Value (ft/day)		149	20	
Percent Value (ft/day)		89.83	7.94	<b>97.77</b>

EQUATION 2: DISCHARGE RATE

Section	length (ft)	k (ft/day)	Average thickness (ft)	Hydr. Grad.	Q (gal/day)
Slag Layer (Model Layer 1)	TB	97.77	2.87	0.004371	62011.10
Clay 1 (Model Layer 2)		0.025	1.28		7.10
Sand 1 (Model Layer 3)		47	1.45		15073.48

**TB Total      77091.68**

EQUATION 3: CONTAMINANT MASS FLUX

Section	Q (gal/day)	Parameter	Average Conc (ug/gal)	Mass Flux (g/day)
100x				
TB	77,092	Cyanide	164.95	<b>12.7</b>
10x				
TB	77,092	Aluminum	2,272.00	<b>138</b>
		Aluminum (diss)	1,466.44	<b>77.5</b>
		Thallium	31.19	<b>2.48</b>
		Thallium (diss)	32.06	<b>2.43</b>

**Appendix C**  
**Coke Point 1 Discharge section**

EQUATION 1: DISCHARGE RATE

Section	length (ft)	k (ft/day)	Average thickness (ft)	Hydr. Grad.	Q (gal/day)
Slag Layer (Model Layer 1)	CP-1	5083	149	5.04	0.017710
Clay 1 (Model Layer 2)			0.025	0.50	
Sand 1 (Model Layer 3)			47	1.00	

**CP-1 Total      536,857.16**

EQUATION 2: CONTAMINANT MASS FLUX

Section	Q (gal/day)	Parameter	Average Conc (ug/gal)	Mass Flux (g/day)
100x				
CP-1	536,857	Naphthalene	443.70	<b>238</b>
10x				
CP-1	536,857	Aluminum	-	-
		Aluminum (diss)	-	-
		Benz[a]anthracene	3.79	<b>2.03</b>
		Thallium	0.40	<b>0.21</b>
		Thallium (diss)	0.29	<b>0.16</b>
		Xylenes	31.09	<b>16.7</b>

**Appendix C**  
**Coke Point 2 Discharge section**

EQUATION 1: DISCHARGE RATE

Section	length (ft)	k (ft/day)	Average thickness (ft)	Hydr. Grad.	Q (gal/day)
Slag Layer (Model Layer 1)	CP-2	3256	149	0.010549	281659.25
Clay 1 (Model Layer 2)			0.025		22.48
Sand 1 (Model Layer 3)			47		21132.14

**CP-2 Total      302813.87**

EQUATION 3: CONTAMINANT MASS FLUX

Section	Q (gal/day)	Parameter	Average Conc (ug/gal)	Mass Flux (g/day)
100x				
CP-2	302,814	Naphthalene	6,376.78	<b>1,931</b>
10x				
CP-2	302,814	Aluminum	6,586.61	<b>1,995</b>
		Aluminum (diss)	7,003.01	<b>2,121</b>
		Benz[a]anthracene	3.36	<b>1.02</b>
		Thallium	22.33	<b>6.76</b>
		Thallium (diss)	37.85	<b>11.5</b>
		Xylene	443.71	<b>134</b>

**Appendix C**  
**Coke Oven Discharge section**

EQUATION 1: DISCHARGE RATE

Section	length (ft)	k (ft/day)	Average thickness (ft)	Hydr. Grad.	Q (gal/day)
Slag Layer (Model Layer 1)	Coke Oven	149	9.21	0.001131	96891.54
Clay 1 (Model Layer 2)		0.025	1.50		2.65
Sand 1 (Model Layer 3)		47	2.81		9329.12

**CO Total    106223.31**

EQUATION 2: CONTAMINANT MASS FLUX

Section	Q (gal/day)	Parameter	Average Conc (ug/gal)	Mass Flux (g/day)
100x				
Coke Oven	106,223	Cyanide	1,816.87	<b>193</b>
		Naphthalene	7,325.81	<b>778</b>
		Xylenes	2,773.08	<b>295</b>
		Benzene	46,033.76	<b>4,890</b>
10x				
Coke Oven	106,223	Benz[a]anthracene	2.51	<b>0.27</b>
		Benzo[a]pyrene	3.06	<b>0.33</b>
		Toulene	9,770.16	<b>1,038</b>
		Ethylbenzene	261.93	<b>27.8</b>
		Thallium	29.65	<b>3.15</b>
		Thallium (diss)	31.29	<b>3.32</b>

**Appendix C**  
**North Western Discharge section**

EQUATION 1: CALCULATION OF CONDUCTIVITY

	Slag LAYER 1						Clay LAYER 2				
	NW	red	blue	black	yellow	Totals	NW	red	black	Totals	
	Segments (ft)	10701	2422	1131	2130	426		10701	1430	1040	
		865	170	1910				1500	3295		
		235		794				1425	1258		
		618							753		
Length (ft)	10701	4140	1301	4834	426	10701	10701	5108	5593	10701	
Percent Length (%)	100	0.39	0.12	0.45	0.04	1.00	100	0.48	0.52	1.00	
Value (ft/day)		149	20	0.561	1200			0.561	0.025		
Percent Value (ft/day)		57.65	2.43	0.25	47.77	<b>60.08</b>		0.27	0.01	<b>0.27</b>	

EQUATION 2: DISCHARGE RATE

	Section	length (ft)	k (ft/day)	Average thickness (ft)	Hydr. Grad.	Q (gal/day)
Slag Layer (Model Layer 1)	NW	10701	60.08	2.98	0.014402	206619.65
Clay 1 (Model Layer 2)			0.27	0.61		188.83
Sand 1 (Model Layer 3)			47	2.06		111345.83

**NW Total      318154.31**

EQUATION 3: CONTAMINANT MASS FLUX

Section	Q (gal/day)	Parameter	Average Conc (ug/gal)	Mass Flux (g/day)
100x				
NW	318,154	Cobalt	156.10	<b>49.7</b>
		Cobalt (diss)	17.03	<b>5.42</b>
		Cyanide	797.25	<b>254</b>
10x				
NW	318,154	Aluminum	1,352.58	<b>430</b>
		Aluminum (diss)	2,088.46	<b>664</b>
		Arsenic	51.01	<b>16.2</b>
		Arsenic (diss)	22.12	<b>7.04</b>
		Manganese	913.46	<b>291</b>
		Manganese (diss)	469.72	<b>149</b>
		Nickel	230.17	<b>73.2</b>
		Nickel (diss)	19.76	<b>6.29</b>
		Iron	20,244.69	<b>6,441</b>
		Iron (diss)	854.15	<b>272</b>

**Appendix C**  
**Hydrologic Unit Thicknesses**

Discharge Area	TOC Elevation (ft)	Total Boring/Well Depth	Depth to water (ft)	Slag Thickness	Wet Slag Thickness	Clay Thickness	Wet Clay Thickness	Sand Thickness	Wet Sand Thickness
<b>Southeast Discharge Area</b>									
Segment SE-3									
B13-021-PZ	14.31	20	17.19	20	2.81	0	0	0	0
B13-066-PZ	6.6	13	6.49	10.5	4.01	2.5	2.5	0	0
B13-069-PZ	23.33	25	23.31	25	1.69	0	0	0	0
B13-001-PZ	19.75	25	8.76	20	11.24	0	0	5	5
Averages	<b>16.00</b>	<b>20.75</b>	<b>13.94</b>	<b>18.88</b>	<b>4.94</b>	<b>0.63</b>	<b>0.63</b>	<b>1.25</b>	<b>1.25</b>
Segment SE-2									
SW-039-MWS	19.91	26	19	25	6	0	0	1	1
SW-040-MWS	13.01	32	8.6	25	16.4	5.5	5.5	1	1
SW-041-MWS	13.47	31.5	8.9	24.5	15.6	7.5	7.5	0	0
SW-042-MWS	7.4	16	6.86	8	1.14	0	0	6	6
SW-043-MWS	10.26	16.5	7.94	0	0	0	0	11	3.06
B13-059-PZ	28.92	40	28.55	35	6.45	0	0	4.5	4.5
Averages	<b>15.50</b>	<b>27.00</b>	<b>13.31</b>	<b>19.58</b>	<b>7.60</b>	<b>2.17</b>	<b>2.17</b>	<b>3.92</b>	<b>2.59</b>
Segment SE-1									
SW-042-MWS	7.4	16	6.86	8	1.14	0	0	6	6
SW-043-MWS	10.26	16.5	7.94	0	0	0	0	11	3.06
SW-044-MWS	8.61	20	9.6	5.08	0	0	0	8.42	3.9
SW-045-MWS	13.1	16	4.3	0.5	0	15.5	11.7	0	0
SW-046-MWS	9.8	18	7.41	14	6.59	0	0	4	4
SW-047-MWS	20.24	20	8.4	19	10.6	1	1	0	0
SW-074-MWS	11.32	14.5	6	5	0	3.83	2.83	5.17	5.17
Averages	<b>11.53</b>	<b>17.29</b>	<b>7.22</b>	<b>7.37</b>	<b>2.62</b>	<b>2.90</b>	<b>2.22</b>	<b>4.94</b>	<b>3.16</b>
Discharge Area	TOC Elevation (ft)	Total Boring/Well Depth	Depth to water (ft)	Slag Thickness	Wet Slag Thickness	Clay Thickness	Wet Clay Thickness	Sand Thickness	Wet Sand Thickness
<b>Turning Basin Discharge Area</b>									
TB									
SW-030-MWS	14.72	14	6.1	6	0	6	5.9	2	2
SW-031-MWS	13.41	14	5	11	6	3	3	0	0
SW-032-MWS	12.64	16	8.06	10	1.94	2	2	4	4
SW-033-MWS	10.28	16	7.1	12	4.9	2	2	1	1
SW-034-MWS	12.62	17	11.37	12.5	1.13	2.5	2.5	2	2
SW-035-MWS	13.43	15	8.7	16	7.3	0	0	0	0
SW-036-MWS	13.38	18	13	18	5	0	0	0	0
SW-037-MWS	13.28	16.1	12.7	12	0	0	0	4.1	3.4
SW-038-MWS	16.28	18	15.65	18	2.35	0	0	0	0
B13-021-PZ	14.31	20	17.19	20	2.81	0	0	0	0
B13-049-PZ	20.13	25	20.01	19.5	0	0	0	5.5	4.99
B13-076-PZ	17.09	20	17.04	20	2.96	0	0	0	0
Averages	<b>14.30</b>	<b>17.43</b>	<b>11.83</b>	<b>14.58</b>	<b>2.87</b>	<b>1.29</b>	<b>1.28</b>	<b>1.55</b>	<b>1.45</b>

**Appendix C**  
**Hydrologic Unit Thicknesses**

Discharge Area	TOC Elevation (ft)	Total Boring/Well Depth	Depth to water (ft)	Slag Thickness	Wet Slag Thickness	Clay Thickness	Wet Clay Thickness	Sand Thickness	Wet Sand Thickness
<b>Coke Point Discharge Area</b>									
Segment CP-1									
CP09-PZM010	7.63	15	6.6	13	6.4	0	0	2	2
CP11-PZM010	8.43	15	7.79	13	5.21	0	0	2	2
CP12-PZM012	5.35	15	4.82	13	8.18	2	2	0	0
CP14-PZM009	13.06	13	12.65	13	0.35	0	0	0	0
Averages	<b>8.62</b>	<b>14.50</b>	<b>7.97</b>	<b>13.00</b>	<b>5.04</b>	<b>0.50</b>	<b>0.50</b>	<b>1.00</b>	<b>1.00</b>
Segment CP-2									
CO58-PZM001	14.31	N/A	14.57	30	15.43	3	3	1	1
CO60-PZP001	15.83	N/A	16.08	23	6.92	5	5	1	1
CO26-PZM007	12.76	N/A	12.92	20	7.08	4	4	1	1
SW14-PZM004	15.85	14	8	6	0	4	2	4	4
Averages	<b>14.69</b>	<b>14.00</b>	<b>12.89</b>	<b>19.75</b>	<b>7.36</b>	<b>4.00</b>	<b>3.50</b>	<b>1.75</b>	<b>1.75</b>
Discharge Area	TOC Elevation (ft)	Total Boring/Well Depth	Depth to water (ft)	Slag Thickness	Wet Slag Thickness	Clay Thickness	Wet Clay Thickness	Sand Thickness	Wet Sand Thickness
<b>Coke Oven Discharge Area</b>									
CO									
CO27-PZM012	5.12	N/A	4.77	20	15.23	3	3	4	4
CO30-PZM015	12.3	N/A	12.57	24	11.43	1	1	3	3
CO36-PZM008	6.94	N/A	7.34	21	13.66	2	2	4	4
CO37-PZM003	12.34	N/A	9.88	19	9.12	4	4	3	3
CO38-PZM006	6.75	N/A	6.82	21	14.18	3	3	4	4
CO101-PZM	12.39	N/A	12.62	24	11.38	2	2	3	3
CO102-PZM	12.88	N/A	13.2	24	10.8	2	2	3	3
CO103-PZM	13.48	N/A	13.7	24	10.3	1	1	3	3
CO104-PZM	13.29	N/A	14.13	25	10.87	0	0	3	3
SW-028-MWS	15.9	14.5	9.28	4	0	0	0	9	3.72
SW-029-MWS	15.75	11.2	11.6	11.2	0	0	0	0	0
SW13-PZM003	16.26	16	12.5	16	3.5	0	0	0	0
Averages	<b>11.95</b>	<b>13.90</b>	<b>10.70</b>	<b>19.43</b>	<b>9.21</b>	<b>1.50</b>	<b>1.50</b>	<b>3.25</b>	<b>2.81</b>
Discharge Area	TOC Elevation (ft)	Total Boring/Well Depth	Depth to water (ft)	Slag Thickness	Wet Slag Thickness	Clay Thickness	Wet Clay Thickness	Sand Thickness	Wet Sand Thickness
<b>Northwest Discharge Area</b>									
NW									
RW-011-PZ	15.15	10	4.8	10	5.2	0	0	0	0
RW-025-PZ	15.28	10	5.97	4	0	0	0	6	4.03
SW-021-MWS	12.83	18	11	18	7	0	0	0	0
SW-022-MWS	14.31	18	12.3	18	5.7	0	0	0	0
SW-023-MWS	14.66	18.5	12.2	12	0	0	0	6.5	6.3
SW-024-MWS	14.03	16	10.33	8	0	6	3.67	2	2
Averages	<b>14.38</b>	<b>15.08</b>	<b>9.43</b>	<b>11.67</b>	<b>2.98</b>	<b>1.00</b>	<b>0.61</b>	<b>2.42</b>	<b>2.06</b>

**Appendix C**  
**Hydraulic Gradients**

Discharge Area	Discharge Distance (ft)	TOC Elevation (ft)	Depth to water (ft)	Groundwater Elevation	Hydraulic Gradient
<b>Southeast Discharge Area</b>					
Segment SE-3					
B13-021-PZ	202	13.89	13.2	0.69	0.003416
B13-066-PZ	318	6.6	6.49	0.11	0.000346
B13-069-PZ	180	23.33	23.31	0.02	0.000111
B13-001-PZ	332	19.75	18.76	0.99	0.002982
<b>Averages</b>	<b>258.00</b>	<b>15.89</b>	<b>15.44</b>	<b>0.45</b>	<b>0.001714</b>
Segment SE-2					
SW-039-MWS	365	19.91	19	0.91	0.002493
SW-040-MWS	94	13.01	8.6	4.41	0.046915
SW-041-MWS	121	13.47	8.9	4.57	0.037769
SW-042-MWS	58	7.4	6.86	0.54	0.009310
SW-043-MWS	202	10.26	7.94	2.32	0.011485
B13-059-PZ	655	28.92	28.55	0.37	0.000565
<b>Averages</b>	<b>249.17</b>	<b>15.50</b>	<b>13.31</b>	<b>2.19</b>	<b>0.018090</b>
Segment SE-1					
SW-042-MWS	58	7.4	6.86	0.54	0.009310
SW-043-MWS	202	10.26	7.94	2.32	0.011485
SW-044-MWS	151	8.61	9.6	-0.99	-0.006556
SW-045-MWS	480	13.1	4.3	8.8	0.018333
SW-046-MWS	188	9.8	7.41	2.39	0.012713
SW-047-MWS	691	20.24	8.4	11.84	0.017135
SW-074-MWS	476	11.32	6	5.32	0.011176
TS10-PDM008	249	6.74	5.81	0.93	0.003735
<b>Averages</b>	<b>311.88</b>	<b>10.93</b>	<b>7.04</b>	<b>3.89</b>	<b>0.009666</b>
Discharge Area	Discharge Distance (ft)	TOC Elevation (ft)	Depth to water (ft)	Groundwater Elevation	Hydraulic Gradient
<b>Turning Basin Discharge Area</b>					
TB					
SW-030-MWS	534	14.72	6.1	8.62	0.016142
SW-031-MWS	492	13.41	5	8.41	0.017093
SW-032-MWS	397	12.64	8.06	4.58	0.011537
SW-033-MWS	390	10.28	7.1	3.18	0.008154
SW-034-MWS	389	12.62	11.37	1.25	0.003213
SW-035-MWS	454	13.43	8.7	4.73	0.010419
SW-036-MWS	319	13.38	13	0.38	0.001191
SW-037-MWS	352	13.28	12.7	0.58	0.001648
SW-038-MWS	637	16.28	15.65	0.63	0.000989
B13-021-PZ	153	14.31	17.19	-2.88	-0.018824
B13-049-PZ	269	20.13	20.01	0.12	0.000446
B13-076-PZ	114	17.09	17.04	0.05	0.000439
<b>Averages</b>	<b>375.00</b>	<b>14.30</b>	<b>11.83</b>	<b>2.47</b>	<b>0.004371</b>

**Appendix C**  
**Hydraulic Gradients**

Discharge Area	Discharge Distance (ft)	TOC Elevation (ft)	Depth to water (ft)	Groundwater Elevation	Hydraulic Gradient
<b>Coke Point Discharge Area</b>					
Segment CP-1					
CP05-PZM008	30	10.33	10	0.33	0.011000
CP05-PZM019	30	10.48	10.12	0.36	0.012000
CP09-PZM010	25	7.63	6.6	1.03	0.041200
CP11-PZM010	42	8.43	7.79	0.64	0.015238
CP12-PZM012	18	5.35	4.82	0.53	0.029444
CP14-PZM009	77	13.06	12.65	0.41	0.005325
CP15-PZM020	66	7.08	6.55	0.53	0.008030
CP16-PZM008	72	20.31	18.91	1.4	0.019444
<b>Averages</b>	<b>45.00</b>	<b>10.33</b>	<b>9.68</b>	<b>0.65</b>	<b>0.017710</b>
Segment CP-2					
CO58-PZM001	169	14.31	14.57	-0.26	-0.001538
CO60-PZP001	190	15.83	16.08	-0.25	-0.001316
CO26-PZM007	79	12.76	12.92	-0.16	-0.002025
CO35-PZM013	34	11.06	10.44	0.62	0.018235
SW14-PZM004	663	15.85	8	7.85	0.011840
TS08-PPM007	21	12.59	11.79	0.8	0.038095
<b>Averages</b>	<b>192.67</b>	<b>13.73</b>	<b>12.30</b>	<b>1.43</b>	<b>0.010549</b>
Discharge Area	Discharge Distance (ft)	TOC Elevation (ft)	Depth to water (ft)	Groundwater Elevation	Hydraulic Gradient
<b>Coke Oven Discharge Area</b>					
Coke Oven					
CO27-PZM012	60	5.12	4.77	0.35	0.005833
CO30-PZM015	41	12.3	12.57	-0.27	-0.006585
CO36-PZM008	52	6.94	7.34	-0.4	-0.007692
CO37-PZM003	58	12.34	9.88	2.46	0.042414
CO38-PZM006	203	6.75	6.82	-0.07	-0.000345
CO101-PZM	27	12.39	12.62	-0.23	-0.008519
CO102-PZM	138	12.88	13.2	-0.32	-0.002319
CO103-PZM	123	13.48	13.7	-0.22	-0.001789
CO104-PZM	31	13.29	14.13	-0.84	-0.027097
TS06-PPM008	112	13.21	12.77	0.44	0.003929
SW-028-MWS	1145	15.9	9.28	6.62	0.005782
SW-029-MWS	744	15.75	11.6	4.15	0.005578
SW13-PZM003	682	16.26	12.5	3.76	0.005513
<b>Averages</b>	<b>262.77</b>	<b>12.05</b>	<b>10.86</b>	<b>1.19</b>	<b>0.001131</b>

**Appendix C**  
**Hydraulic Gradients**

Discharge Area	Discharge Distance (ft)	TOC Elevation (ft)	Depth to water (ft)	Groundwater Elevation	Hydraulic Gradient
<b>Northwest Discharge Area</b>					
NW					
RW-011-PZ	264	15.15	4.8	10.35	0.039205
RW-025-PZ	247	15.28	5.97	9.31	0.037692
RW19-PZM000	192	13.49	9.05	4.44	0.023125
RW20-PZM000	161	12.82	4.41	8.41	0.052236
SW-021-MWS	916	12.83	11	1.83	0.001998
SW-022-MWS	839	14.31	12.3	2.01	0.002396
SW-023-MWS	702	14.66	12.2	2.46	0.003504
SW-024-MWS	560	14.03	10.33	3.7	0.006607
SW07-PZM004	815	14.52	16	-1.48	-0.001816
GL-02 (-5)	253	23.171	21.45	1.721	0.006802
GL-05 (-7)	333	25.892	23.98	1.912	0.005742
GL-12 (-3)	505	13.32	9.89	3.43	0.006792
GL-15 (-6)	375	15.792	12.33	3.462	0.009232
GL-16 (-6)	241	20.921	16.74	4.181	0.017349
TS-01 (-7)	176	20.048	19.14	0.908	0.005159
<b>Averages</b>	<b>438.60</b>	<b>16.42</b>	<b>12.64</b>	<b>3.78</b>	<b>0.014402</b>

**Appendix C**  
**100x and 10x the Surface Water Criteria**  
**Parameter Concentrations**

Coke Oven	100x				10x					
	Benzene ug/L	Cyanide ug/L	Naphthalene ug/L	Xylenes ug/L	Benz[a]anthracene ug/L	Benzo[a]pyrene ug/L	Ethylbenzene ug/L	Thallium Dissolved ug/L	Thallium ug/L	Toluene ug/L
CO27-PZM012	16100	-	5670	1500	1	1	171	-	-	5390
CO28-PZM010	20900	-	146	436	1	1	36.6	-	-	1080
CO29-PZM010	15.1	-	193	50	1	1	25	-	-	25
CO30-PZM015	52800	-	1830	1060	1	1	71.3	-	-	3620
CO32-PZM004	0.35	-	1	2	1	1	1	-	-	1
CO36-PZM008	21300	-	723	1370	0.22	0.32	54.3	-	-	4610
CO37-PZM003	22100	-	1730	3750	-	-	375	-	-	15900
CO38-PZM006	10700	-	6620	2120	1	1	269	-	-	7210
CO101-PZM	17400	-	2150	249	0.33	0.25	21.3	-	-	1220
CO102-PZM	15700	-	875	238	0.22	1	19.6	-	-	1150
CO103-PZM	27700	-	12300	960	0.3	1	55.5	-	-	1980
CO104-PZM	16.5	-	5.5	3	1	1	1	-	-	1.1
CO121	1970	-	324	642	1	1	61.7	-	-	1650
TS06-PPM008	7.3	-	1.1	20	1.1	1.1	10	-	-	2.9
SW-028-MWS	1	10	0.082	3	0.053	0.033	1	4.8	3.5	1
SW-029-MWS	3.6	1420	162	3	0.066	1.2	1	10	10	0.49
SW13-PZM003	20.4	9.9	169	47.7	0.33	0.04	2	10	10	35.6
Averages	12,160.84	479.97	1,935.28	732.57	0.66	0.81	69.19	8.27	7.83	2,581.01

Coke Point-1	100x		10x				
	Naphthalene ug/L	Aluminum ug/L	Aluminum Dissolved ug/L	Benz[a]anthracene ug/L	Thallium ug/L	Thallium Dissolved ug/L	Xylenes ug/L
CP05-PZM008	142	-	-	1	0.018	-	8.3
CP05-PZM019	180	-	-	1	0.01	-	8.8
CP09-PZM010	61.5	-	-	1	0.017	0.1	1.9
CP11-PZM010	92.8	-	-	1	0.1	0.022	7.9
CP12-PZM012	80.5	-	-	1	0.5	0.1	16.7
CP14-PZM009	42.9	-	-	1	0.04	-	5.6
CP15-PZM020	319	-	-	1	0.1	0.066	11.2
CP16-PZM008	19	-	-	1	0.055	0.1	5.3
Averages	117.21	-	-	1.00	0.11	0.08	8.21

Coke Point-2	100x		10x				
	Naphthalene ug/L	Aluminum ug/L	Aluminum Dissolved ug/L	Benz[a]anthracene ug/L	Thallium ug/L	Thallium Dissolved ug/L	Xylenes ug/L
CO58-PZM001	3040	-	-	1	-	-	249
CO60-PZP001	676	-	-	1	-	-	73.9
CO10-PZM006	1.9	-	-	1	-	-	2
CO26-PZM007	6130	-	-	1	-	-	337
CO35-PZM013	210	-	-	1	-	-	38.4
SW14-PZM004	49.5	1740	1850	0.33	10	5.9	3
Averages	1684.57	1740.00	1850.00	0.89	10.00	5.90	117.22

**Appendix C**  
**100x and 10x the Surface Water Criteria**  
**Parameter Concentrations**

Turning Basin	100x		10x							
	Cyanide ug/L	Aluminum ug/L	Aluminum Dissolved ug/L	Thallium ug/L	Thallium Dissolved ug/L					
SW-030-MWS	64.6	766	698	<b>10</b>	4.8					
SW-031-MWS	6.1	320	83.5	<b>10</b>	<b>10</b>					
SW-032-MWS	32.4	266	93.8	<b>10</b>	<b>10</b>					
SW-033-MWS	81.1	881	49.8	4.2	6.1					
SW-034-MWS	71.8	249	224	<b>10</b>	4.5					
SW-035-MWS	225	124	126	5.3	<b>10</b>					
SW-036-MWS	<b>10</b>	636	363	7	4.7					
SW-037-MWS	4.6	770	699	<b>10</b>	<b>10</b>					
SW-038-MWS	<b>10</b>	250	249	<b>10</b>	<b>10</b>					
B13-021-PZ	3.2	-	150	-	<b>10</b>					
B13-049-PZ	4.1	-	107	-	<b>10</b>					
B13-076-PZ	<b>10</b>	-	343	-	<b>10</b>					
Averages	43.58	473.56	265.51	<b>8.50</b>	8.34					
100x										
SE-3	Cobalt ug/L	Cobalt Dissolved ug/L	Manganese ug/L	Manganese Dissolved ug/L	Aluminum ug/L	Aluminum Dissolved ug/L	Iron ug/L	Iron Dissolved ug/L	Nickel ug/L	Nickel Dissolved ug/L
B13-021-PZ	-	<b>5</b>	-	0.94	-	150	-	<b>70</b>	-	1.2
B13-066-PZ	-	<b>5</b>	-	1.2	-	83	-	25	-	<b>10</b>
B13-069-PZ	-	<b>5</b>	-	1.1	-	96	-	17	-	16.8
B13-001-PZ	-	<b>5</b>	-	<b>5</b>	-	158	-	<b>70</b>	-	1.7
Averages	-	<b>5.00</b>	-	<b>2.06</b>	-	121.75	-	<b>45.50</b>	-	7.43
SE-2	Cobalt ug/L	Cobalt Dissolved ug/L	Manganese ug/L	Manganese Dissolved ug/L	Aluminum ug/L	Aluminum Dissolved ug/L	Iron ug/L	Iron Dissolved ug/L	Nickel ug/L	Nickel Dissolved ug/L
SW-039-MWS	<b>5</b>	<b>5</b>	1.6	<b>5</b>	125	120	13	<b>70</b>	<b>10</b>	1
SW-040-MWS	<b>5</b>	<b>5</b>	71.2	62.4	1150	453	1500	127	0.78	0.82
SW-041-MWS	5.9	5.6	362	362	60	42.2	12600	13400	6.7	6.3
SW-042-MWS	40.2	41.6	954	982	1200	1220	4110	4360	31.2	32.7
SW-043-MWS	29.8	30.9	1070	1170	1560	1540	10700	11100	30.3	30.3
SG07-PDM008	<b>5</b>	<b>5</b>	<b>5</b>	<b>5</b>	892	884	<b>70</b>	<b>70</b>	<b>10</b>	<b>10</b>
B13-059-PZ	-	<b>5</b>	-	<b>5</b>	-	310	-	<b>70</b>	-	<b>10</b>
Averages	<b>15.15</b>	<b>14.01</b>	<b>410.63</b>	<b>370.20</b>	<b>831.17</b>	<b>652.74</b>	<b>4832.17</b>	<b>4171.00</b>	<b>14.83</b>	<b>13.02</b>
SE-1	Cobalt ug/L	Cobalt Dissolved ug/L	Manganese ug/L	Manganese Dissolved ug/L	Aluminum ug/L	Aluminum Dissolved ug/L	Iron ug/L	Iron Dissolved ug/L	Nickel ug/L	Nickel Dissolved ug/L
SW-042-MWS	40.2	41.6	954	982	1200	1220	4110	4360	31.2	32.7
SW-043-MWS	29.8	30.9	1070	1170	1560	1540	10700	11100	30.3	30.3
SW-044-MWS	7.7	6.4	3060	3430	425	55.7	63400	53700	15.4	14.4
SW-045-MWS	64.7	65.1	1140	1100	603	625	1010	1450	103	105
SW-046-MWS	214	216	11500	11200	420	162	12600	14100	100	100
SW-047-MWS	100	105	884	850	2810	2860	83.2	30.4	99.4	106
SW-074-MWS	3.8	2.6	275	215	118	51	176	<b>70</b>	3.8	3.4
TS10-PDM008	<b>5</b>	<b>5</b>	75.1	79	23	18.4	<b>70</b>	<b>70</b>	1.6	1.6
Averages	<b>58.15</b>	<b>59.08</b>	<b>2369.76</b>	<b>2,378.25</b>	<b>894.88</b>	<b>816.51</b>	<b>11518.65</b>	<b>10610.05</b>	<b>48.09</b>	<b>49.18</b>

**Appendix C**  
**100x and 10x the Surface Water Criteria**  
**Parameter Concentrations**

NW	100x			10x						
	Cobalt ug/L	Cobalt Dissolved ug/L	Cyanide ug/L	Aluminum ug/L	Aluminum Dissolved ug/L	Arsenic ug/L	Arsenic Dissolved ug/L	Iron ug/L	Iron Dissolved ug/L	Manganese ug/L
RW-011-PZ	-	<b>5</b>	<b>10</b>	-	540	-	6.4	-	44.4	-
RW-025-PZ	-	<b>5</b>	4.5	-	1540	-	10.1	-	51.9	-
RW19-PZM000	1.5	-	1330	248	-	14.6	-	448	-	0.89
RW20-PZM000	<b>5</b>	-	215	315	-	118	-	103	-	3.8
SW-021-MWS	<b>5</b>	<b>5</b>	<b>10</b>	576	512	<b>5</b>	5.4	74.8	20.4	19
SW-022-MWS	<b>5</b>	<b>5</b>	<b>10</b>	325	267	<b>5</b>	<b>5</b>	53.4	29.4	15
SW-023-MWS	<b>5</b>	<b>5</b>	<b>10</b>	806	804	<b>5</b>	<b>5</b>	45.3	34.4	4.2
SW-024-MWS	<b>5</b>	<b>5</b>	296	182	149	4	4	727	249	264
SW07-PZM004	1.3	1.5	<b>10</b>	49.2	<b>50</b>	<b>5</b>	<b>5</b>	3150	1150	619
GL-02 (-5)	0.92	-	-	-	-	5	-	789	-	199
GL-05 (-7)	170	-	-	-	-	4.4	-	37200	-	768
GL-12 (-3)	74.9	-	-	-	-	0.37	-	11100	-	444
GL-15 (-6)	0.32	-	-	-	-	2.5	-	105	-	57.4
GL-16 (-6)	262	-	-	-	-	3.2	-	15700	-	742
TS-01 (-7)	0.13	-	-	-	-	3.1	-	29.6	-	0.76
<b>Averages</b>	<b>41.24</b>	<b>4.50</b>	<b>210.61</b>	<b>357.31</b>	<b>551.71</b>	<b>13.47</b>	<b>5.84</b>	<b>5348.08</b>	<b>225.64</b>	<b>241.31</b>

**10x (cont.)**

NW	Manganese Dissolved ug/L	Nickel ug/L	Nickel Dissolved ug/L
RW-011-PZ	3.9	-	1.2
RW-025-PZ	1	-	3.6
RW19-PZM000	-	0.076	-
RW20-PZM000	-	0.66	-
SW-021-MWS	13.2	0.85	<b>10</b>
SW-022-MWS	1.8	0.78	<b>10</b>
SW-023-MWS	3.7	1.4	0.94
SW-024-MWS	245	<b>10</b>	0.8
SW07-PZM004	600	<b>10</b>	<b>10</b>
GL-02 (-5)	-	18.8	-
GL-05 (-7)	-	245	-
GL-12 (-3)	-	108	-
GL-15 (-6)	-	11.2	-
GL-16 (-6)	-	382	-
TS-01 (-7)	-	1.7	-
<b>Averages</b>	<b>124.09</b>	<b>60.81</b>	<b>5.22</b>

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## **APPENDIX D**

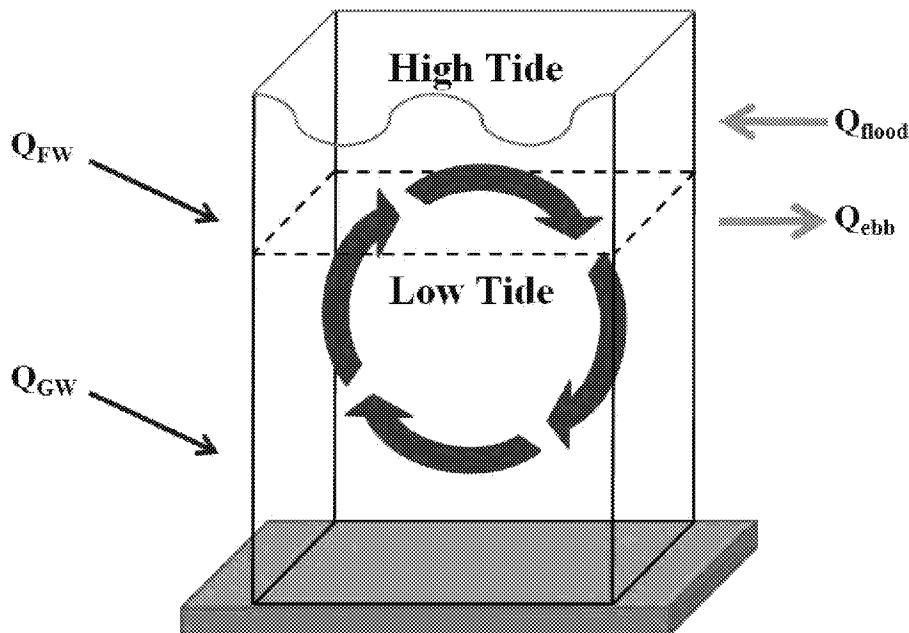
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## APPENDIX D

### TIDAL PRISM MODEL APPROACH

A detailed description of the tidal prism model is presented in this appendix. It is assumed that each water body subject to the tidal prism model is well mixed. The volume of each water body fluctuates with tidal action. Control Volumes (CVs) have been established for the Turning Basin, Jones Creek, and Old Road Bay, as pictured in the attached CV diagrams. The tidal prism represents the difference in the volume of the water body between high and low tides. Water flows into the water body on the flood tide (along with minor contributions of groundwater and other freshwater flows), mixes within the CV, and flows out on the following ebb tide. The primary flows in the tidal prism model are illustrated in the graphic below.



**Figure A-1 – Schematic Diagram for the Tidal Prism Model**

Each of the volumetric flowrates is represented by a  $Q$  symbol with different subscripts representing the different flow pathways. The volumetric flowrate is expressed per tidal cycle. The flood tide is the volume of water that enters the water body through the neighboring water body boundary (Patapsco River for the Turning Basin and Old Road Bay) during the complete tidal cycle. The ebb tide is the volume of water that leaves the water body through the neighboring water body boundary during the complete tidal cycle. Each CV has groundwater (GW) flow inputs, and Jones Creek and Old Road Bay have additional freshwater (FW) inputs. It should be noted that additional GW inputs to Jones Creek and Old Road Bay from neighboring properties beyond Sparrows Point are expected to be negligible and are not included.

Based on the CVs shown in the attached diagrams, the mass balances of water for each tidal body can be written as follows:

**EQ1.** Turning Basin:

$$\frac{dV}{dt} = Q_{flood} + Q_{GW} - Q_{ebb}$$

Jones Creek and Old Road Bay are linked water bodies, and so their equations have subscripts to represent the contributions of flow to and from each individual water body.

**EQ2.** Jones Creek:

$$\frac{dV_1}{dt} = Q_{flood1} + Q_{GW1} + Q_{FW1} - Q_{ebb1}$$

**EQ3.** Old Road Bay:

$$\frac{dV_2}{dt} = Q_{flood2} + Q_{GW2} + Q_{FW2} - Q_{ebb2} - Q_{flood1} + Q_{ebb1}$$

**EQ4.** Jones Creek and Old Road Bay (combined CV):

$$\frac{dV}{dt} = Q_{flood2} + Q_{GW2} + Q_{FW2} + Q_{GW1} + Q_{FW1} - Q_{ebb2}$$

Each flowrate ( $Q$ ) has a corresponding concentration of a contaminant of interest, denoted by the  $X$  symbol with the same subscript. The mass balance of a contaminant of interest for each water body can be written as follows:

**EQ5.** Turning Basin:

$$\frac{dVX}{dt} = Q_{flood}X_{flood} + Q_{GW}X_{GW} - Q_{ebb}X_{ebb}$$

Jones Creek and Old Road Bay are linked water bodies, and so their equations have subscripts to represent the contributions of flow to and from each individual water body.

**EQ6.** Jones Creek:

$$\frac{dV_1X_{V1}}{dt} = Q_{flood1}X_{flood1} + Q_{GW1}X_{GW1} + Q_{FW1}X_{FW1} - Q_{ebb1}X_{ebb1}$$

**EQ7.** Old Road Bay:

$$\frac{dV_2 X_{V2}}{dt} = Q_{flood2} X_{flood2} + Q_{GW2} X_{GW2} + Q_{FW2} X_{FW2} - Q_{ebb2} X_{ebb2} - Q_{flood1} X_{flood1} \\ + Q_{ebb1} X_{ebb1}$$

**EQ8.** Jones Creek and Old Road Bay (combined CV):

$$\frac{dVX}{dt} = Q_{flood2} X_{flood2} + Q_{GW2} X_{GW2} + Q_{FW2} X_{FW2} + Q_{GW1} X_{GW1} + Q_{FW1} X_{FW1} \\ - Q_{ebb2} X_{ebb2}$$

In a steady state condition, each rate can be simplified by setting  $dV/dt = 0$ . Thus each concentration can be isolated and solved for algebraically. It should also be noted that the concentration of the contaminant of interest in each basin is equal to the concentration in the ebb tide ( $X_{ebb}$ ) since the assumption is that the water body is well mixed. In addition, the concentrations in the flood tides ( $X_{flood}$ ) into the Turning Basin and Old Road Bay, as well as the concentrations in the freshwater inputs ( $X_{FW}$ ) are all assumed to be 0.

These equations and assumptions are sufficient to solve for the concentrations within each basin when the groundwater concentrations ( $X_{GW}$ ) are known, but do not take the recirculation rate of ebb tides into consideration. This recirculation ratio ( $R$ ) is representative of the proportion of the flood tide which is comprised of water which exited the water body on the previous ebb tide. For the simplest example (Turning Basin), the total flood tide is comprised of two components: clean water from Patapsco River ( $X = 0$ ) and recirculated ebb waters with the same concentration as the water body itself ( $X_V$ ). Therefore a representative concentration ( $X_{flood}$ ) can be calculated for the net flood tide, as follows:

**EQ9.** Net Flood Tide:

$$Q_{flood} = Q_{flood(clean)} + Q_{flood(recirc)}$$

**EQ10.** Net Flood Tide:

$$Q_{flood} X_{flood} = Q_{flood(clean)} X_{flood(clean)} + Q_{flood(recirc)} X_{flood(recirc)}$$

**EQ11 & 12.** Net Flood Tide:

$$X_{flood} = \frac{Q_{flood(recirc)} X_V}{Q_{flood}} \quad Q_{flood(recirc)} = (R) Q_{flood}$$

Therefore, it is shown that the representative recirculated concentration ( $X_{flood}$ ) is equal to the recirculation ratio ( $R$ ) multiplied by the concentration in the water body itself ( $X_V$ ). This simple

model can be applied directly to the flooding equations for both the Turning Basin and Old Road Bay. The derivation for the representative flooding concentration is more complex for Jones Creek because the flood tide originates in Old Road Bay (not the Patapsco River), which is not assumed to be clean. While slightly more complex, the principles of the derivation for the representative flooding concentration into Jones Creek remain the same.

Using the equations above and accounting for the recirculation ratio, the following mass balance can be derived to determine the contaminant concentration in the Turning Basin:

**EQ13.** Turning Basin:

$$X_V = \frac{Q_{GW} X_{GW}}{(1 - R) Q_{flood} + Q_{GW}}$$

The following mass balance can be derived to determine the concentration in Old Road Bay:

**EQ14.** Old Road Bay:

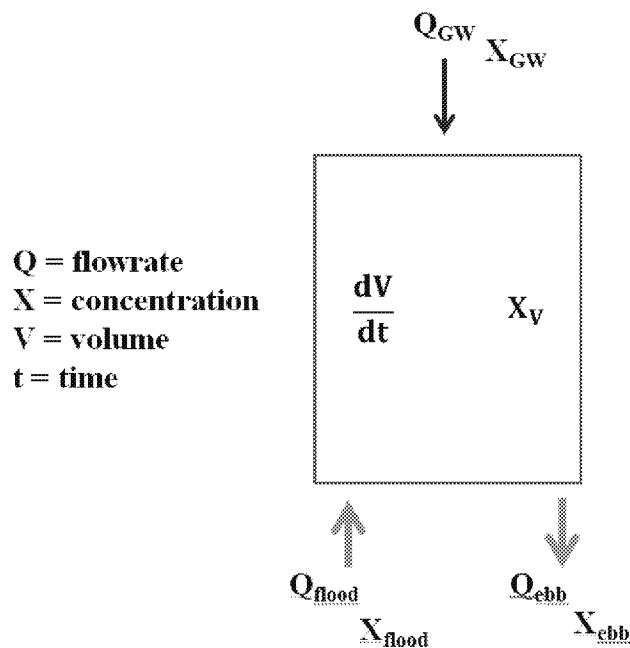
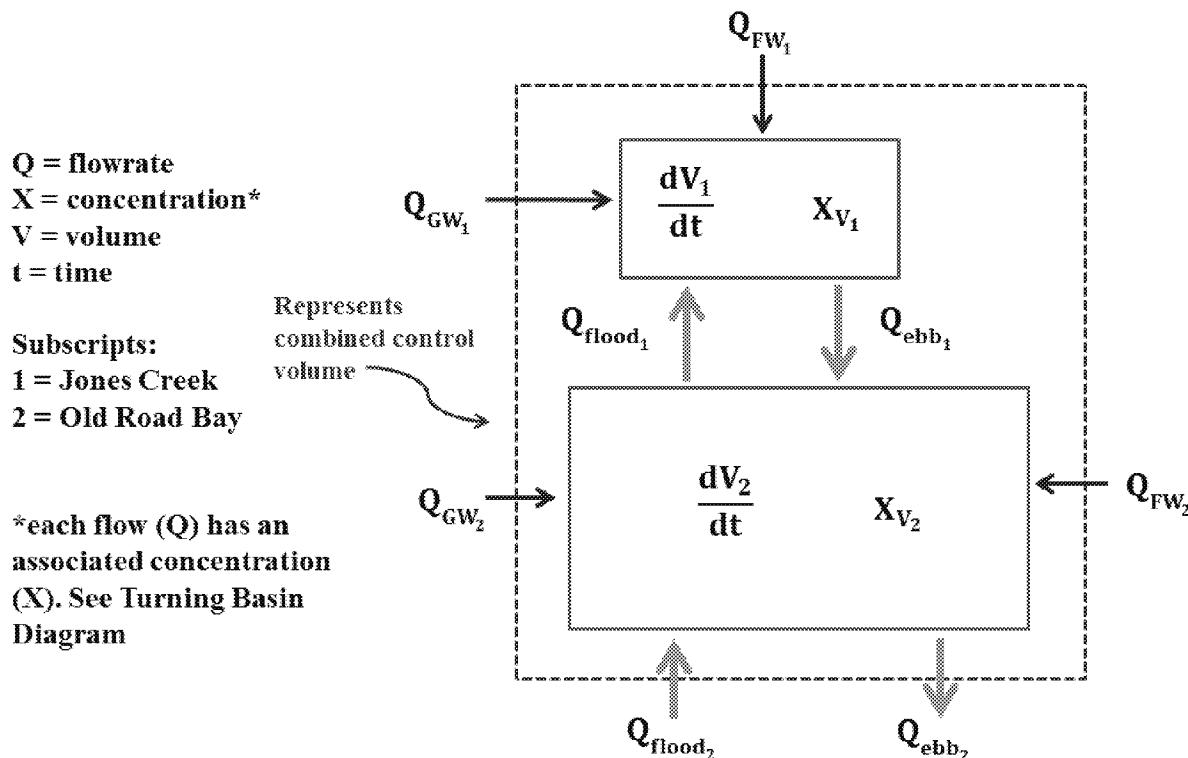
$$X_{V2} = \frac{Q_{GW2} X_{GW2} + Q_{GW1} X_{GW1}}{Q_{ebb2} - (R) Q_{flood2}}$$

Note that this equation explicitly includes GW concentration terms from both Jones Creek (subscript 1) and Old Road Bay (subscript 2) because the water bodies are connected and these GW flows influence the concentrations in both. The equation to determine the concentration in Jones Creek explicitly includes the  $X_{V2}$  concentration term. The following mass balance can be derived to determine the concentration in Jones Creek:

**EQ15.** Jones Creek:

$$X_{V1} = \frac{Q_{flood1} (1 - R) X_{V2} + Q_{GW1} X_{GW1}}{Q_{ebb1} - (R) Q_{flood1}}$$

More detailed derivations of these final concentration equations (13, 14, and 15), with algebraic simplification, are provided in the attached computation spreadsheets. All groundwater and freshwater volumetric flowrates ( $Q_{GW}$  and  $Q_{FW}$ ) are known or were calculated from separate equations. The flooding flowrates for each basin ( $Q_{flood}$ ) were calculated by taking the difference between the volume of the water body at high tide and low tide (i.e., the tidal prism), while accounting for the additional freshwater and groundwater inputs over the same time period during the flood tide. The high and low tide volumes were obtained from a combination of waterway navigational charts, historical tidal monitoring stations, and area measurements from Geographic Information Systems (GIS) software. The specific computations of the flooding flowrates are also given in the attached computation spreadsheets.

**Figure A-2 - Turning Basin Control Volume Diagram****Figure A-3 – Jones Creek and Old Road Bay Control Volume(s) Diagram**

**Tidal Prism Model**  
**Derivation and Example Calculations**

**Turning Basin**

[Dimensions]

**Key Parameters**

T = Time for one complete tidal cycle = 12 hr 25 min = 0.5174 days	T
$T_1$ = Number of complete tidal cycles from high to low tide, or low to high tide = 0.5	T
$T_2$ = Represents a complete tidal cycle = $2*T_1 = 1$	T
$Q_{flood}$ = Volumetric Inflow of tidal water during flood phase, averaged over full tidal cycle ( $T_2$ )	L3/T
$Q_{GW}$ = Volumetric Inflow of groundwater, per tidal cycle ( $T_2$ )	L3/T
$V_{midtide}$ = Water Body Volume at mid-tide	L3
$V_{high}$ = Water Body Volume at high-tide	L3
$V_{low}$ = Water Body Volume at low-tide	L3

**Key Equations**

$$V_{high} = V_{low} + Q_{GW} * T_1 + Q_{flood} * T_2$$

$$Q_{flood} = (V_{high} - V_{low} - Q_{GW} * T_1) / T_2$$

**Equation Inputs**

Symbol	Type/Source	Units	Value
T (days per tidal cycle)	constant	days/cycle	0.5174
$T_1$ (1/2 tidal cycle)	constant	cycles	0.5
$T_2$ (1 tidal cycle)	constant	cycles	1.0
Area	GIS Measurement	$m^2$	410,000
Avg Depth (Mid-Tide assumed )	Nav. Charts	ft	35
Depth Decrease (Low Tide)	CH2MHill Report	ft	1
Depth Increase (High Tide)	CH2MHill Report	ft	1
$Q_{GW}$	separate calculation	gal/day	77,092
Avg Depth (Mid-Tide assumed )	calculation	m	10.67
Depth Decrease (Low Tide)	calculation	m	0.30
Depth Increase (High Tide)	calculation	m	0.30
$V_{midtide}$	calculation	$m^3$	4,373,880
$V_{low}$	calculation	$m^3$	4,248,912
$V_{high}$	calculation	$m^3$	4,498,848
$Q_{GW}$	calculation	$m^3/cycle$	151
$Q_{flood}$	calculation	$m^3/cycle$	249,861

## Tidal Prism Model Derivation and Example Calculations

Jones Creek

[Dimensions]

### Key Parameters

T = Time for one complete tidal cycle = 12 hr 25 min = 0.5174 days	T
$T_1$ = Number of complete tidal cycles from high to low tide, or low to high tide = 0.5	T
$T_2$ = Represents a complete tidal cycle = $2*T_1 = 1$	T
$Q_{flood}$ = Volumetric Inflow of tidal water during flood phase, averaged over full tidal cycle ( $T_2$ )	L3/T
$Q_{GW}$ = Volumetric Inflow of groundwater, per tidal cycle ( $T_2$ )	L3/T
$Q_{FW}$ = Volumetric Inflow of fresh streamwater, per tidal cycle ( $T_2$ )	L3/T
$V_{midtide}$ = Water Body Volume at mid-tide	L3
$V_{high}$ = Water Body Volume at high-tide	L3
$V_{low}$ = Water Body Volume at low-tide	L3

### Key Equations

$$V_{high} = V_{low} + Q_{GW} * T_1 + Q_{FW} * T_1 + Q_{flood} * T_2$$

$$Q_{flood} = (V_{high} - V_{low} - Q_{GW} * T_1 - Q_{FW} * T_1) / T_2$$

### Equation Inputs

Symbol	Type/Source	Units	Value
T (days per tidal cycle)	constant	days/cycle	0.5174
$T_1$ (1/2 tidal cycle)	constant	cycles	0.5
$T_2$ (1 tidal cycle)	constant	cycles	1.0
Area	GIS Measurement	$m^2$	530,000
Avg Depth (Mid-Tide assumed)	Nav. Charts	ft	5
Depth Decrease (Low Tide)	CH2MHill Report	ft	1
Depth Increase (High Tide)	CH2MHill Report	ft	1
$Q_{GW}$	separate calculation	gal/day	287,485
$Q_{FW}$ (Jones Creek)	separate calculation	gal/day	1,337,405
Avg Depth (Mid-Tide assumed)	calculation	m	1.52
Depth Decrease (Low Tide)	calculation	m	0.30
Depth Increase (High Tide)	calculation	m	0.30
$V_{midtide}$	calculation	$m^3$	807,720
$V_{low}$	calculation	$m^3$	646,176
$V_{high}$	calculation	$m^3$	969,264
$Q_{GW}$	calculation	$m^3/cycle$	563
$Q_{FW}$ (Jones Creek)	calculation	$m^3/cycle$	2,619
$Q_{flood}$	calculation	$m^3/cycle$	321,497

**Tidal Prism Model**  
**Derivation and Example Calculations**

**Old Road Bay**

[Dimensions]

**Key Parameters**

$T = \text{Time for one complete tidal cycle} = 12 \text{ hr } 25 \text{ min} = 0.5174 \text{ days}$	$T$
$T_1 = \text{Number of complete tidal cycles from high to low tide, or low to high tide} = 0.5$	$T$
$T_2 = \text{Represents a complete tidal cycle} = 2*T_1 = 1$	$T$
$Q_{\text{flood}} = \text{Volumetric Inflow of tidal water to Old Road Bay during flood phase, averaged over full tidal cycle (T}_2)$	$L3/T$
$Q_{\text{flood\_JC}} = \text{Volumetric Inflow of tidal water to Jones Creek during flood phase, averaged over tidal cycle (T}_2) \rightarrow$	<div style="border: 1px solid black; padding: 2px; margin-right: 10px;">321,497</div> <div style="margin-right: 10px;">(m<sup>3</sup>/cyc.)</div> <div style="text-align: right;">L3/T</div>
$Q_{\text{GW}} = \text{Volumetric Inflow of groundwater to Old Road Bay, per tidal cycle (T}_2)$	L3/T
$Q_{\text{FW}} = \text{Volumetric Inflow of fresh streamwater to Old Road Bay from North Point Creek, per tidal cycle (T}_2)$	L3/T
$V_{\text{midtide}} = \text{Water Body Volume at mid-tide}$	L3
$V_{\text{high}} = \text{Water Body Volume at high-tide}$	L3
$V_{\text{low}} = \text{Water Body Volume at low-tide}$	L3

**Key Equations**

$$V_{\text{high}} = V_{\text{low}} + Q_{\text{GW}} * T_1 + Q_{\text{FW}} * T_1 + Q_{\text{flood}} * T_2 - Q_{\text{flood\_JC}} * T_2$$

$$Q_{\text{flood}} = (V_{\text{high}} - V_{\text{low}} - Q_{\text{GW}} * T_1 - Q_{\text{FW}} * T_1 + Q_{\text{flood\_JC}} * T_2) / T_2$$

**Equation Inputs**

Symbol	Type/Source	Units	Value
$T$ (days per tidal cycle)	constant	days/cycle	0.5174
$T_1$ (1/2 tidal cycle)	constant	cycles	0.5
$T_2$ (1 tidal cycle)	constant	cycles	1.0
Area	GIS Measurement	m <sup>2</sup>	2,700,000
Avg Depth (Mid-Tide assumed)	Nav. Charts	ft	7
Depth Decrease (Low Tide)	CH2MHill Report	ft	1
Depth Increase (High Tide)	CH2MHill Report	ft	1
$Q_{\text{GW}}$	separate calculation	gal/day	916,954
$Q_{\text{FW}}$ (North Point Creek)	separate calculation	gal/day	834,701
$Q_{\text{FW}}$ (Pennwood Canal)	BRWWTP Effluent	gal/day	13,700,000
Avg Depth (Mid-Tide assumed)	calculation	m	2.13
Depth Decrease (Low Tide)	calculation	m	0.30
Depth Increase (High Tide)	calculation	m	0.30
$V_{\text{midtide}}$	calculation	m <sup>3</sup>	5,760,720
$V_{\text{low}}$	calculation	m <sup>3</sup>	4,937,760
$V_{\text{high}}$	calculation	m <sup>3</sup>	6,583,680
$Q_{\text{GW}}$	calculation	m <sup>3</sup> /cycle	1,796
$Q_{\text{FW}}$ (Total)	calculation	gal/day	14,534,701
$Q_{\text{FW}}$ (Total)	calculation	m <sup>3</sup> /cycle	28,465
$Q_{\text{flood}}$	calculation	m <sup>3</sup> /cycle	1,952,286

**Tidal Prism Model**  
**Derivation and Example Calculations**

**Turning Basin - Mass Balance**

[Dimensions]

**Key Parameters**

V = Volume of Turning Basin	L3
t = Time	T
X <sub>v</sub> = Concentration of parameter X within Turning Basin	M/L3
X <sub>GW</sub> = Concentration of parameter X in groundwater	M/L3
X <sub>flood</sub> = Concentration of parameter X in flood tide waters = 0	M/L3
X <sub>ebb</sub> = Concentration of parameter X in ebb tide waters = X <sub>v</sub>	M/L3
Q <sub>GW</sub> = Volumetric Inflow of groundwater, per tidal cycle	L3/T
Q <sub>flood</sub> = Volumetric Inflow of tidal water during flood phase, averaged over full tidal cycle	L3/T
Q <sub>ebb</sub> = Volumetric Outflow of tidal water during ebb phase, averaged over full tidal cycle	L3/T
R = Recirculation Fraction. Fraction of flood tide derived from recirculated water	-

**Key Equations**

$$dV/dt = 0 = Q_{flood} + Q_{GW} - Q_{ebb}$$

$$Q_{ebb} = Q_{flood} + Q_{GW}$$

$$Q_{ebb} * X_{ebb} = Q_{flood} * X_{flood} + Q_{GW} * X_{GW}$$

$$(Q_{flood} + Q_{GW}) * X_v = Q_{flood} * X_{flood} + Q_{GW} * X_{GW}$$

$$Q_{flood} = Q_{flood(clean)} + Q_{flood(recirculate)}$$

$$Q_{flood} * X_{flood} = Q_{flood(clean)} * 0 + Q_{flood(recirculate)} * X_v$$

$$X_{flood} = Q_{flood(recirculate)} * X_v / Q_{flood}$$

$$X_{flood} = Q_{flood} * R * X_v / Q_{flood}$$

$$X_{flood} = R * X_v$$

$$(Q_{flood} + Q_{GW}) * X_v = Q_{flood} * R * X_v + Q_{GW} * X_{GW}$$

$$Q_{flood} * X_v + Q_{GW} * X_v = Q_{flood} * R * X_v + Q_{GW} * X_{GW}$$

$$X_v * (1-R) * Q_{flood} + Q_{GW} * X_v = Q_{GW} * X_{GW}$$

$$X_v = Q_{GW} * X_{GW} / ((1-R) * Q_{flood} + Q_{GW})$$

**Equation Inputs**

Symbol	Type/Source	Units	Value
R	constant	-	0.78
X <sub>GW</sub>	separate calculation	ug/L	473.56
Q <sub>GW</sub>	calculation	m <sup>3</sup> /cycle	151
Q <sub>flood</sub>	calculation	m <sup>3</sup> /cycle	249,861
X <sub>v</sub>	calculation	ug/L	1.30

← Concentration in GW Discharge  
to Turning Basin

← Concentration in Turning Basin

**Tidal Prism Model**  
**Derivation and Example Calculations**

**Jones Creek and Old Road Bay - Mass Balance**

[Dimensions]

**Key Parameters**

$V_1$ = Volume of Jones Creek	L3
$V_2$ = Volume of Old Road Bay	L3
$V$ = Volume of full water body including Jones Creek and Old Road Bay	L3
$t$ = Time	T
$X_{v1}$ = Concentration of parameter X within Jones Creek	M/L3
$X_{v2}$ = Concentration of parameter X within Old Road Bay	M/L3
$X_{GW1}$ = Concentration of parameter X in groundwater inflow to Jones Creek	M/L3
$X_{GW2}$ = Concentration of parameter X in groundwater inflow to Old Road Bay	M/L3
$X_{FW1}$ = Concentration of parameter X in freshwater inflow to Jones Creek = 0	M/L3
$X_{FW2}$ = Concentration of parameter X in freshwater inflow (North Point Creek + Pennwood Canal) to Old Road Bay = 0	M/L3
$X_{flood1}$ = Concentration of parameter X in flood tide waters into Jones Creek = $X_{v2}$	M/L3
$X_{flood2}$ = Concentration of parameter X in flood tide waters into Old Road Bay = 0	M/L3
$X_{ebb1}$ = Concentration of parameter X in ebb tide waters out of Jones Creek = $X_{v1}$	M/L3
$X_{ebb2}$ = Concentration of parameter X in ebb tide waters out of Old Road Bay = $X_{v2}$	M/L3
$Q_{GW1}$ = Volumetric Inflow of groundwater to Jones Creek, per tidal cycle	L3/T
$Q_{GW2}$ = Volumetric Inflow of groundwater to Old Road Bay, per tidal cycle	L3/T
$Q_{FW1}$ = Volumetric Inflow of freshwater to Jones Creek, per tidal cycle	L3/T
$Q_{FW2}$ = Volumetric Inflow of freshwater (North Point Creek + Pennwood Canal) to Old Road Bay, per tidal cycle	L3/T
$Q_{flood1}$ = Volumetric Inflow of tidal water to Jones Creek from Old Road Bay during flood phase, averaged over full tidal cycle	L3/T
$Q_{flood2}$ = Volumetric Inflow of tidal water to Old Road Bay during flood phase, averaged over full tidal cycle	L3/T
$Q_{ebb1}$ = Volumetric Outflow of tidal water from Jones Creek to Old Road Bay during ebb phase, averaged over full tidal cycle	L3/T
$Q_{ebb2}$ = Volumetric Outflow of tidal water from Old Road Bay during ebb phase, averaged over full tidal cycle	L3/T
R = Recirculation Fraction. Fraction of flood tide derived from recirculated water (used for both basins)	-

**Key Equations**

Using full control volume (V), derive  $X_{v2}$

(Could also use individual Old Road Bay control volume)

$$dV/dt = 0 = Q_{flood2} + Q_{GW2} + Q_{FW2} + Q_{GW1} + Q_{FW1} - Q_{ebb2}$$

$$Q_{ebb2} = Q_{flood2} + Q_{GW2} + Q_{FW2} + Q_{GW1} + Q_{FW1}$$

$$Q_{ebb2} * X_{ebb2} = Q_{flood2} * X_{flood2} + Q_{GW2} * X_{GW2} + Q_{FW2} * X_{FW2} + Q_{GW1} * X_{GW1} + Q_{FW1} * X_{FW1}$$

$$X_{ebb2} = X_{v2} ; X_{FW1} = 0 ; X_{FW2} = 0 ; X_{flood2} = R * X_{v2}$$

$$Q_{ebb2} * X_{v2} = Q_{flood2} * R * X_{v2} + Q_{GW2} * X_{GW2} + Q_{GW1} * X_{GW1}$$

$$(Q_{ebb2} - Q_{flood2} * R) * X_{v2} = Q_{GW2} * X_{GW2} + Q_{GW1} * X_{GW1}$$

$$X_{v2} = (Q_{GW2} * X_{GW2} + Q_{GW1} * X_{GW1}) / (Q_{ebb2} - Q_{flood2} * R)$$

$Q_{ebb2}$  given above

Using control volume of Jones Creek ( $V_1$ ), derive  $X_{v1}$

$$dV_1/dt = 0 = Q_{flood1} + Q_{GW1} + Q_{FW1} - Q_{ebb1}$$

$$Q_{ebb1} = Q_{flood1} + Q_{GW1} + Q_{FW1}$$

$$Q_{ebb1} * X_{ebb1} = Q_{flood1} * X_{flood1} + Q_{GW1} * X_{GW1} + Q_{FW1} * X_{FW1}$$

$$X_{ebb1} = X_{v1} ; X_{FW1} = 0$$

$$X_{flood1} = X_{v1} * R + X_{v2} * (1-R)$$

$$Q_{ebb1} * X_{v1} = Q_{flood1} * X_{flood1} + Q_{GW1} * X_{GW1}$$

simplify ↓

$$X_{v1} = (Q_{flood1} * (1-R) * X_{v2} + Q_{GW1} * X_{GW1}) / (Q_{ebb1} - Q_{flood1} * R)$$

$Q_{ebb1}$  and  $X_{v2}$  given above

**Equation Inputs**

Symbol	Type/Source	Units	Value
R	constant	-	0.78
$X_{GW1}$	separate calculation	ug/L	58.15
$X_{GW2}$	separate calculation	ug/L	15.15
$Q_{GW1}$	calculation	$m^3/cycle$	563
$Q_{GW2}$	calculation	$m^3/cycle$	1,796
$Q_{ebb2}$	calculation	$m^3/cycle$	1,985,730
$Q_{flood2}$	calculation	$m^3/cycle$	1,952,286
$X_{v2}$ (Old Road Bay)	calculation	ug/L	0.13
$Q_{flood1}$	calculation	$m^3/cycle$	321,497
$Q_{ebb1}$	calculation	$m^3/cycle$	324,679
$X_{v1}$ (Jones Creek)	calculation	ug/L	0.57

← Concentration in GW Discharge to Jones Creek

← Concentration in GW Discharge to Old Road Bay

← Concentration in Old Road Bay

← Concentration in Jones Creek